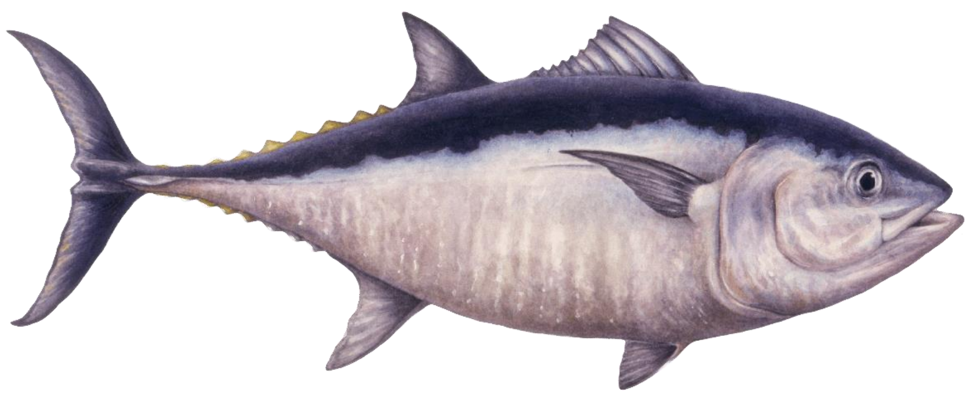
Bluefin Tuna

Thunnus thynnus



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Mediterranean Sea

Croatia, Cyprus, Greece, Italy, Malta, Spain, Tunisia, and Turkey, with minor operations in Libya and Morocco

Net Pens

Aquaculture Standard Version A2

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Final Seafood Recommendation

Bluefin tuna
Mediterranean Sea
Net pens

Criterion	Score (0-10)	Rank	Critical?
C1 Data	6.11	YELLOW	
C2 Effluent	5.00	YELLOW	NO
C3 Habitat	4.27	YELLOW	NO
C4 Chemicals	10.00	GREEN	NO
C5 Feed	0.00	CRITICAL	YES
C6 Escapes	10.00	GREEN	NO
C7 Disease	5.00	YELLOW	NO
C8 Source	0.00	RED	
C9X Wildlife mortalities	-5.00	YELLOW	NO
C10X Introduced species escape	0.00	GREEN	
Total	**35.38**		
Final score	**4.42**		

OVERALL RANKING

Final Score	4.42
Initial rank	YELLOW
Red criteria	2
Interim rank	RED
Critical Criteria?	YES

FINAL RANK
RED

Scoring note –scores range from 0 to 10 where 0 indicates very poor performance and 10 indicates the aquaculture operations have no significant impact. Color ranks: red = 0 to 3.33, yellow = 3.34 to 6.66, green = 6.66 to 10. Criteria 9X and 10X are exceptional criteria, where 0 indicates no impact and a deduction of -10 reflects very poor performance. Two or more red criteria trigger a red final result.

Summary
The final numerical score for net pen farming of bluefin tuna in the Mediterranean is 4.42 out of 10. The presence of two Critical Red criteria (Feed, Source of Stock) automatically results in an overall Red recommendation of "Avoid."

Executive Summary

This assessment was originally published in December 2016 and reviewed for any significant changes in February 2021. Please see Appendix 2 for details of review.

Farming of Atlantic bluefin tuna (*Thunnus thynnus*, referred to as "bluefin tuna" for the remainder of this report unless specified) in the Mediterranean is a capture-based aquaculture practice that uses wild-caught individuals as captive farm stock (in addition to globally sourced wild-caught baitfish as feed). This farming practice clearly overlaps with the wild fisheries sector, and industry management is influenced by both aquaculture and wild fishery regulations.

Ten Mediterranean countries are currently involved in bluefin tuna farming: Croatia, Cyprus, Greece, Italy, Malta, Spain, Tunisia, and Turkey, with minor operations in Libya and Morocco; though authorized to farm, Cyprus and Greece have not produced bluefin tuna since 2014. Bluefin tuna farming involves the capture and rearing of tuna in marine net pens for a period from 2 to 10 months (for "fattening"), and up to 2–3 years (for juvenile rearing or "farming"). According to the International Commission for the Conservation of Atlantic Tunas (ICCAT), bluefin tuna rearing operations are classified as "fattening" if captive rearing and husbandry is completed between 2 and 10 months using mature spawners (minimum size: 30 kg or 115 cm). In contrast, the operation is classified as "farming" if rearing is done for a longer period (1 to > 3 years) and involves juvenile fish (min. size: 8–30 kg or 75 cm); farming is only performed in Croatia. The majority of bluefin tuna production in the Mediterranean (78%) consists of the fattening of adult tuna (> 30 kg) that are reared for less than 1 year. In contrast, only 22% of tuna aquaculture focuses on the rearing of juvenile tuna over 1–3 years (Croatia). In fattening operations, all captive tuna are harvested during the same season in which they were caught, and a substantial fallow period is created when net pens are unoccupied between the harvest period of one rearing cycle and the stocking period of the next (3–9 months); in some cases, when market price is not high enough, fish are continued to the next season to reach a greater weight and sale price. In contrast, overlapping production cycles in juvenile-rearing operations eliminate seasonal fallow periods completely. Because key aspects of this Seafood Watch assessment are similar for both "fattening" and "farming" operations (i.e., the capture of the bluefin stock and the efficiency of use and sourcing of baitfish), the specific type of farming operation is only distinguished where relevant throughout this report. Otherwise, the general term "farming" is used interchangeably for both "fattening" and "farming."

At the farm level, production data from farmers are scarce and rearing conditions are often treated by many farmers as confidential. Furthermore, bluefin production reporting to international regulatory agencies is highly variable, and scientific interest often focuses more on the economic aspects of farmed tunas rather than related environmental impacts. At the national level, there is limited access to regulatory data and information on wildlife interactions and disease interactions, and escape statistics are rarely available. Although some laws and regulations in the Mediterranean relevant to bluefin tuna farming are still under elaboration, the environmental impacts of tuna farming within the European Union (EU) are currently regulated and managed using a large variety of European Commission (EC) directives and international conventions. Though the framework for these regional regulations is widely accessible, limited details or gaps in publicly available data exist in some key areas for bluefin tuna farming. Overall, because of the relatively new establishment of tuna farming legislation and the lack of publicly available regulatory data in some Mediterranean countries (especially non-EU members), data availability to assess the Mediterranean bluefin tuna farming industry's operations and impacts is considered to be moderate. The Criterion 1 - Data score is 6.11 out of 10.

Throughout their history in the Mediterranean, bluefin tuna farms have continued to use net pens and whole baitfish feed as the sole rearing technique in the region. All discharged effluent, consisting of uneaten baitfish and solid/soluble waste, is released unmitigated from the net pens into the surrounding environment. As a result, effluent waste has been detected at considerable distances from farm sites (3 km in some instances). Tuna farming is expected to have an overall greater environmental impact than that of traditional Mediterranean farmed species due to a comparatively higher FCR and higher waste outputs, but the seasonal fallow period and dispersive nature of farm sites typically results in few significant impacts reported beyond the immediate farm area. The majority of studies indicate that bluefin tuna farms have little impact on water quality, and the overall benthic impacts are minor and fairly confined in space due to the diffusion and dilution of waste beyond the immediate vicinity of the farm, at dispersive sites. Whereas only minor impacts exist beyond the immediate farm location for dispersive farming sites, depositional locations can produce significant benthic impacts. Furthermore, although the regional impact of bluefin tuna farming is unlikely to cause severe changes in the overall nutrient loading status of the Mediterranean Sea, European Commission regulatory controls for both site-specific and cumulative impacts lack robust measures for waste management. Overall, the lack of significant impacts beyond the immediate farm area, combined with ongoing uncertainties regarding the regulation of both site-specific and cumulative impacts, result in a low to moderate Effluent Criterion score of 5 out of 10.

In bluefin tuna farming, the floating net pens have a minimal direct habitat impact, and benthic impacts produced by individual farms are generally limited to an area directly beneath the farm site and only occasionally farther away. Given the relatively confined nature of benthic impacts, the potential for cumulative impacts from adjacent sites or from the industry's total impact area are considered low. Benthic impacts below fattening farms are largely reversible by fallowing, but the presence of captive tuna year-round at juvenile tuna farming sites has caused significant impact to the benthos. For Habitat Conversion and Function (Factor 3.1), the combination of minor or reversible impacts beneath fattening farms and significant losses in habitat functionality at juvenile tuna farms results in a score of 5 out of 10. Although the majority of tuna farming countries have instituted distance limits for farm sites and recently adopted allocated zones for aquaculture (AZA) to manage habitat impacts, variable environmental impact assessment (EIA) requirements and poor transparency in regulatory management have contributed to varying levels of farm siting effectiveness in the Mediterranean. Furthermore, national standards for preventing critical habitat damage are regionally inconsistent. For Habitat and Farm Siting Management (Factor 3.2), the mixed level of implementation for habitat regulations and the subsequent development of significant benthic impacts result in a score of 2.8 out of 10. When combined, these conditions result in an overall moderate Criterion 3 - Habitat score of 4.27 out of 10.

Bluefin tuna farming practices currently do not employ pesticides, antibiotics, hormones, or other chemical therapeutants during the production cycle. Copper is used as an antifoulant on aquaculture nets in the Mediterranean, but there is no literature indicating the use of copper antifoulants in tuna farming, or significant metal concentrations beneath tuna farms. Overall, the absence of chemicals and antibiotic use, combined with the lack of evidence for copper-based benthic impacts, result in a low level of concern and a Criterion 4 - Chemical Use score of 10 out of 10.

Mediterranean bluefin tuna farms, like all bluefin tuna farms globally, rely solely on the use of whole, wild baitfish for feed. Unlike almost all other aquaculture industries that are focused on growing their farmed stock, the primary goal of the majority of Mediterranean tuna operations is to increase the tuna's fat content, alongside weight gain for market desirability. Thus, the feed conversion ratio is typically high. Reported economic feed conversion ratios (eFCR) vary from 10–15 for farming juveniles and up to 20–30 for the fattening of adult tuna. The exclusive use of whole feedfish at these FCR values produces a critically high FI:FO ratio (a simple measure of wild fish use) and a score of 0 out of 10. In the wild, tuna also consume baitfish, but do so as part of a complex natural foodweb and ecosystem. The extraction of these two ecosystem components (i.e., the tuna and the baitfish) and their use as inputs in an artificial farming system does not enable them to provide the same ecosystem services. Though sardine, mackerel, and herring represent the most common feed ingredients, a variety of baitfish species is utilized as feed, and the majority are imported globally from foreign fisheries. A precautionary Source Fishery Sustainability score of –6 out of –10 was applied to Factor 5.1 (Wild Fish Use), producing a final adjusted score that remained 0 out of 10. Furthermore, a net protein loss greater than 90% and the presence of a significant feed footprint (143.04 ha per ton of farmed fish) represent additional environmental concerns. Overall, the absence of by-products and non-edible processing ingredients as alternative sources of feed protein, and the highly inefficient conversion of feed into harvestable fish, result in a critical Criterion 5 - Feed score of 0 out of 10.

For net pen aquaculture, there is an inherent risk of escape from catastrophic losses or more chronic "leakage." But given that farmed tuna are the product of capture-based aquaculture and that captive tuna originate from the Mediterranean, the risk of ecological impact of escaped tuna on other wild species or wild counterparts is considered to be minimal. The resulting Criterion 6 - Escape score is 10 out of 10.

Although bluefin tuna farms are strongly associated with high pathogen prevalence, disease-related mortality in the Mediterranean is generally low. Despite reports of several bacterial outbreaks that resulted in mortality at juvenile tuna farms in the Adriatic Sea, few regulatory measures are currently employed for pathogen control in the Mediterranean. There is currently no evidence that pathogens or parasites within bluefin tuna farms are causing significant population declines in wild tuna stocks or other wild species; however, the lack of regulatory health measures and the well-documented interactions between wild bluefin tuna and aquaculture operations warrant ongoing concern for potential disease transfer between farmed and wild species. These conditions result in a Criterion 7 - Disease score of 5 out of 10 on a precautionary basis.

Mediterranean bluefin tuna farms are considered to be 100% reliant on threatened wild tuna populations due to the industry-wide dependence on wild-caught individuals for farm stock. Therefore, the Criterion 8 - Source of Stock score is 0 out of 10.

Dolphins, seals, and sharks are the primary wildlife species interacting with bluefin tuna farms and associated purse-seiners, but interactions are rare. For dolphins and seals, Mediterranean fish farms (seabream and sea bass) employ non-lethal methods to deter predators (per EU regulations), though there is no indication they are used at tuna farms. Few reporting obligations exist for bluefin tuna farming, resulting in exceptionally little robust data on their impact to dolphin and seal populations, though mortalities associated with tuna farming are unlikely to cause population level impacts. The lack of statistical data available for both farm-related wildlife mortalities and purse seine bycatch, combined with the endangered status of several involved species and the potential for underreporting, result in a precautionary approach to scoring this criterion. The final score for Criterion 9X - Wildlife Mortalities is –5 out of –10.

In Mediterranean bluefin tuna farming, wild stocks are captured and transported to net pens within the same waterbody, so the unintentional introduction of non-native species does not occur. The final score for Criterion 10X - Escape of unintentionally introduced species is 0 out of –10.

In summary, the final numerical score for net pen farming of bluefin tuna in the Mediterranean is 4.42 out 10. This numerical score results in an initial overall Yellow recommendation; however, the presence of two Critical Red criteria (Feed, Source of Stock) results in an overall Red recommendation of “Avoid.”

Table of Contents

Introduction

Scope of the analysis and ensuing recommendation

Species
Atlantic bluefin tuna *(Thunnus thynnus)*

Geographic coverage
Mediterranean Sea: includes Croatia, Cyprus, Greece, Italy, Malta, Spain, Tunisia, and Turkey, with minor operations in Libya and Morocco.

Production Method
Net pens

Species Overview

Bluefin tuna is a large, pelagic marine fish. In the Eastern Atlantic, this fish ranges from the Lofoten Islands off the coast of northern Norway south to the Canary Islands as well as the Mediterranean Sea. Well known for its distinct physiology, bluefin tuna is an endothermic fish species possessing the unique ability to maintain internal temperatures through metabolic processes (Korsmeyer and Dewar 2001). Bluefin must swim constantly to maintain a continuous flow of water over its gills and is continually in search of food to maintain its high metabolism. Juvenile and adult tuna generally prey on fish, squid, and crustaceans. Mature tuna, which feed primarily on pelagic fishes, are associated with the top of the trophic food web and migrate seasonally over long distances between temperate waters where they feed, and tropical waters where they spawn. In the eastern Atlantic, the main spawning grounds for bluefin tuna are at sites throughout the Mediterranean, particularly in the area of the Balearic Islands in the western Sea (Figure 1). Reaching sexual maturity between the ages of 3 and 5, bluefin tuna may form giant schools spreading over several nautical miles when migrating into the Mediterranean Sea to spawn during the summer months. This schooling behavior makes bluefin highly vulnerable to exploitation by commercial fisheries.

Production system

In the Mediterranean, the majority of bluefin tuna farming is carried out in relatively exposed sites and only occasionally in offshore sites (GFCM 2011b). Wild bluefin tuna are captured alive by purse seine and transferred via tow cages to farm sites consisting of anchored, floating net pens. Bluefin tuna farms are located at varying distances from shore, from 0.2 km to > 6 km, although most farms are established at 2 to 5 km from the coast. The average net pen depth is 30 m and the average water column depth is 50 m (GFCM 2005). Net pens are usually placed in areas where a minimum height of 10 m or more is left between the bottom of the net pen and the seafloor. On a given farm site, up to 2,000 bluefin tuna may be confined in a single net pen, with eight or more net pens typically grouped together (Weber 2003). The majority of bluefin tuna production in the Mediterranean (87%) consists of the fattening of adult tuna (>30 kg) that are reared for less than 1 year (often between 2 and 10 months). In contrast, only 13% of tuna aquaculture focuses on the rearing of juvenile tuna over 1–3 years (http://www.iccat.int/en/ffb.asp, last accessed 8/2016); an aquaculture method specific to the Adriatic Sea (Croatia). Both aquaculture practices are included in this assessment.

The scope of this assessment is farmed bluefin tuna, in the Mediterranean Sea, in net pens. Other terms used to describe bluefin tuna farming include *ranching*, *penning*, *on-growing*, and *mariculture*.

Fishery information

Declared catches in the East Atlantic and Mediterranean reached a peak of over 60,000 metric tons (MT) in 2007 (ICCAT 2012b), and then decreased substantially in 2008 following stronger regulatory measures that enforced a considerable reduction in total allowable catch (TAC), further reduction of the tuna fishing season and fishing area, freezing and reduction of fleet capacity, and a freeze on farm capacity in the Mediterranean. These recent developments have significantly reduced tuna aquaculture in the area. Total allowable catch (TAC) dropped from 32,000 MT in 2003 to 12,900 MT in 2012 and was set at 13,400 MT for 2013 and 2014 (ICCAT 2012b) (ICCAT 2013a). The most recent stock assessment indicated increases in spawning stock biomass (SSB), and ICCAT recommended compounding TAC increases of 20% for the following 3 years; currently, the TAC is 19,296 MT (ICCAT 2015 BFT 14-04). In 2011, Mediterranean bluefin tuna was listed as “Endangered” by the International Union for the Conservation of Nature (IUCN), as well as a “Species of Concern” by NOAA, based on data indicating a 63% decline over a recent 20-year period (1985–2005) (Abdul Malak et al. 2011). These listings prompted the establishment of the Mediterranean Sea and Eastern Atlantic Ocean Bluefin Tuna Recovery Plan in 2008 (Abdul Malak et al. 2011) (NOAA 2013) (ICCAT 2014). The conservation and enforcement measures of the recovery plan resulted in a substantial decrease in catch and a three- to four-fold increase in juvenile abundance from 2009–2012 (ICCAT 2014). The Mediterranean continues to be the dominant production area for farmed bluefin tuna in the Atlantic.

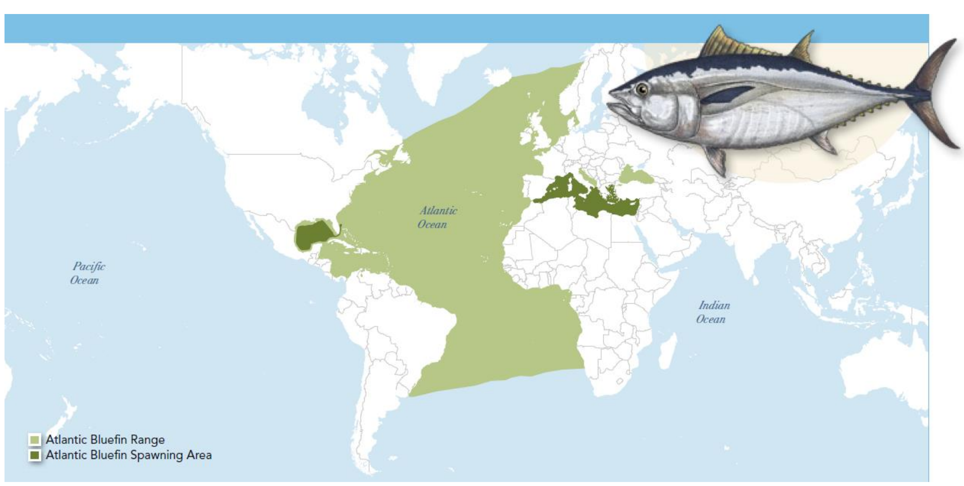

Figure 1. Home range and spawning area of (Atlantic) bluefin tuna (Source: Boustany, 2011).

Bluefin tuna aquaculture in the Mediterranean Sea

Bluefin tuna farming has been reported in the Mediterranean since the mid-1980s (Spain), but a significant industry expansion began more recently in the mid-1990s (Cardia and Lovatelli 2007). Beginning in 1985, tuna farming in the Mediterranean started in the Andalusia Province in Spain and expanded in 1996 to Croatia, in 2000 to Malta, and in 2001 to Italy. By 2004, the East Atlantic/Mediterranean bluefin tuna stock provided 95% of the global catch, and a continuing increase in catch for tuna farming has further contributed to a sharp decline in population size (Mylonas et al. 2010).

Though tuna fattening farms exist throughout the Mediterranean, juvenile rearing operations are found exclusively in Croatia because of its historical presence dating to the early 1990s (Ottolenghi 2008) (Mylonas et al. 2010). Currently, there are 55 actively operating bluefin tuna farms that are recognized by ICCAT, and the highest production volumes in recent years have come from Italy, Malta, and Spain.

After the development of tuna farming in the Mediterranean, a large increase in fishery efficiency and capacity occurred, in which purse seining fleets were converted into providers of live tuna for farm production. Purse seiners are the exclusive supplier to the tuna farming industry. After the tuna are captured, they are transferred to tow cages and transported by tugboat to farm sites, where circular floating net pens are situated in both inshore and offshore locations. Transportation trips may last days, weeks, or months depending on the distance to the net pens. Mortality rates during the fattening/farming period have been recorded at ≈2%–3% (Ottolenghi 2008) (Mylonas et al. 2010). Mortality rates during transportation are also low (1%–2%), although there have been rare cases where all the fish have died (Ottolenghi 2008).

In recent years, 44% of allocated bluefin catches in the Mediterranean have been made by purse seiners that set on free schools of tuna (ISSF 2013). Close to 100% of the purse seine catch is sold to bluefin tuna farming operations throughout the Mediterranean (Mylonas et al. 2010). Farms obtain wild tuna from local fishing fleets as well as from vessels bearing other flags. The annual bluefin tuna purse seine season is currently open for several weeks during May and June, and the subsequent harvest period coincides closely with seasonal demand and the availability of wild-caught tuna in Japan, to realize optimum market value.

Unlike other types of marine aquaculture, the main objective of fattening operations is not solely to increase biomass, but to provide bluefin tuna markets with the desired flesh quality required for sushi and sashimi (high fat content) (Mylonas et al. 2010). In contrast to fattening, juvenile bluefin farming in the Adriatic (Croatia) functions specifically to grow the fish and increase body weight to reach the minimum harvestable size acceptable to market standards (30–50 kg) (Ticina et al. 2007). Harvested juvenile tuna do not obtain the highest price in the Japanese market, but maintaining them any longer involves increased business risk and is not generally practiced (Mylonas et al. 2010).

Farmed bluefin production statistics

Bluefin is the only tuna species farmed in the Mediterranean. ICCAT maintains a database of authorized bluefin tuna farms and lists 55 active farms (Figure 2) with a maximum potential capacity of 59,462 MT (http://www.iccat.int/en/ffb.asp, last accessed 8/2016). Annual production of bluefin tuna from these operations is difficult to estimate, primarily due to the scarcity of reliable data and the difficulty in quantifying the weight and size composition of live tuna at the time of capture.

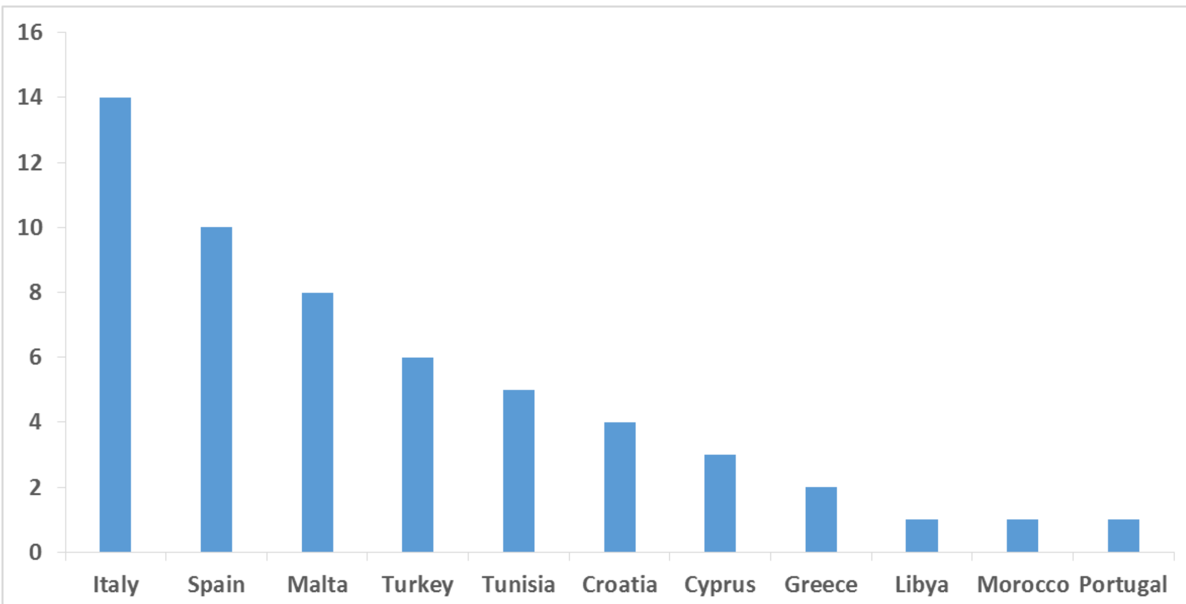

Figure 2. Number of bluefin tuna farms authorized by ICCAT, 2016.

Both European Commission (Eurostat) and FAO (FIGIS) production statistics appear limited when compared to the potential capacity of ICCAT-authorized bluefin tuna farms. As a result of missing data or potential reporting errors, Eurostat production statistics are not available for many Member States (Cyprus, Greece, Italy) and a similar problem exists with FIGIS (Turkey, Libya, Morocco) (Tables 1 & 2).

FISHREG: Mediterranean and Black Sea
UNIT: Tonnes live weight
AQUAMETH: Cages
SPECIES: Atlantic bluefin tuna - Thunnus thynnus
AQUAENV: Total

TIME ▸	2012	2013	2014	2015
GEO ▾				
Greece	:	:	:	:
Spain	2,339	2,250	2,587.25	:
Croatia	1,907	2,616	2,223.76	:
Italy	:	:	:	:
Cyprus	:	:	:	:
Malta	3,904	6,123*(p)*	5,451.43	:
Portugal	:	:	:	:
Turkey	:	:	:	:

Table 1. EC Eurostat annual aquaculture production of Mediterranean bluefin tuna. The total harvest recorded for 2014 is 10,262 MT.

Land Area	Ocean Area	Environment	Species	Scientific name	2012	2013	2014
Croatia	Mediterranean and Black Sea	Marine	Atlantic bluefin tuna	Thunnus thynnus	1 125 *F*	915 *F*	1 605 *F*
Greece	Mediterranean and Black Sea	Marine	Atlantic bluefin tuna	Thunnus thynnus	30 *F*	55 *F*	75 *F*
Italy	Mediterranean and Black Sea	Marine	Atlantic bluefin tuna	Thunnus thynnus	85 *F*	85 *F*	20 *F*
Malta	Mediterranean and Black Sea	Marine	Atlantic bluefin tuna	Thunnus thynnus	800 *F*	2 312 *F*	1 762 *F*
Spain	Mediterranean and Black Sea	Marine	Atlantic bluefin tuna	Thunnus thynnus	555 *F*	305 *F*	320 *F*
Tunisia	Mediterranean and Black Sea	Marine	Atlantic bluefin tuna	Thunnus thynnus	220 *F*	630 *F*	96 *F*
Turkey	Mediterranean and Black Sea	Marine	Atlantic bluefin tuna	Thunnus thynnus	395 *F*	470 *F*	305 *F*
Grand total					3 210 *F*	4 772 *F*	4 183 *F*

Table 2. FAO FIGIS annual aquaculture production of Mediterranean bluefin tuna.

Despite the obligation of EU Member States to provide bluefin tuna production statistics (Annex III of Regulation (EC) No 788/96), there are circumstances where Member States have not fully complied, resulting in countries with reduced production numbers or no data altogether. Spain is the only Member State that has regularly communicated information on the production of farmed bluefin tuna (Martín, 2007).

According to the Standing Committee on Research and Statistics (SCRS), 86.8% of Mediterranean bluefin tunas were captured by purse seine in 2012, equaling 6,094 MT (ICCAT 2014). This quantity cannot be directly translated into farm production for several reasons: (1) the lack of accurate methods of estimating size and length at capture; (2) overlapping production cycles for juvenile tuna farming; (3) evidence of tuna laundering; and (4) the presence of illegal, unreported, and unregulated (IUU) catches. These are elaborated below:

1. Currently, there is no standardized system of determining bluefin tuna growth under captive conditions (Galaz, 2012). The key point in the collection of statistics from tuna farming remains the measurement/estimation of the initial number and weight of the fish introduced to the net pens (Lovatelli 2005). Accurate techniques to quantify weight

and size composition for fast moving, live fish remain difficult. The most advanced methods currently available include underwater video cameras or acoustic methods (Lovatelli 2005). This lack of biometric information makes stock assessment and, subsequently, management and conservation of Mediterranean bluefin extremely difficult. Without accurate initial length or weight measurements of the fish during the farming period, the total regional production, growth, and feed conversion rates are only rough estimates.

2. In juvenile tuna farming, only part of a seasonal catch is landed during the current year, and the rest are landed in the following 1–3 years (Miyake et al. 2003). This means there can be a large gap between the amount of fish introduced to net pens and the amount harvested in the same annual season. Farming operations in Croatia, representing 13% of Mediterranean farming capacity, are continuously stocked with tuna and the production cycles have significant overlap (Mylonas et al. 2010), in which some catches from 2–3 years back can be landed at any harvest (Miyake et al. 2003). Therefore, landings/harvests have no relation to catches. These elements contribute to increasing uncertainties in regional bluefin production.

3. Bluefin Statistical Document Program (BFSD) and tuna laundering:

   ICCAT introduced the BFSD Program for frozen tuna in 1993 and fresh-killed tuna in 1994. According to the Program, ICCAT members are obligated to request any bluefin products, when imported to their lands, to be accompanied by a BFSD in which the weight of products by flag of the fishing vessels, general area, and type of the products have to be recorded. The major objective of the Program is to identify unreported catches of bluefin tuna (mostly by IUU fishing vessels).

   Unfortunately, the BFSD is only required for dead fresh or frozen tuna products, and the international trade of live tuna is not subject to the documents. Thus, live tuna can be imported from any country without any documentation. Furthermore, trade between EU countries is not considered foreign trade and hence there is no need for a BFSD regardless of the condition of fish (live or dead). Once fish are stocked in net pens, the origin of the fish is lost. Consequently, the quantities of bluefin tuna exports from one country can exceed their real (reported) catches by a significant quantity (Miyake et al. 2003). The laundering of live tuna continues to significantly complicate the management of bluefin tuna farming in the Mediterranean.

4. According to ICCAT (2012a), catches of bluefin tuna from the eastern Atlantic and Mediterranean were seriously underreported from the mid-1990s to 2007 as a result of illegal, unreported, and unregulated (IUU) catches. Although IUU catches of Mediterranean bluefin tuna decreased dramatically in 2008 after the establishment of strong enforcement and enhanced monitoring regulations, trade-based estimation data suggest that excess catches of 57% were made between 2008 and 2011 (Gagern 2013).

ICCAT continues to maintain a list of known IUU vessels on its website, with listings added as recently as 2014 (http://www.iccat.int/en/IUU.asp).

Although strong efforts have been placed on enforcing bluefin catch limits (fishing, transferring, and harvesting) over the last 10 years (pers. comm., Hellenic Center for Marine Research 2015) and the majority of IUU catches are made by other fleets (pers. comm., Anonymous 2015), the laundering of live tuna and IUU catches continues to significantly complicate the management of bluefin tuna farming in the Mediterranean.

When evaluated as a whole, production data by EUROSTAT and FIGIS, and catch data by SCRS yield limited values for Mediterranean farmed bluefin tuna production. Overall, production figures are considered highly variable at this time (pers. comm., Malta Aquaculture Research Centre 2015).

Import and export sources and statistics

Since its inception, nearly all Mediterranean bluefin aquaculture production has been exported to Japan. Because of bluefin's large size and the color, texture, and high fat content of their meat, it is the most sought-after species for sashimi, and commands a higher price than any other species of tuna (Joseph, 2003). The main bluefin tuna consumption period in Japan occurs during the holiday season in December, where many festivities mark the end of the year. The entire tuna farming and fattening industry in the Mediterranean is based on supplying this Japanese tradition (Ottolenghi 2008).

Farmed bluefin tuna sold in Japan are concentrated in the hands of 5–10 Japanese trading houses; most notably, the Tsukiji Fish Market in Tokyo. Annual consumption of bluefin tuna in Japan is approximately 50,000 MT per year, of which Mediterranean farmed bluefin make up approximately 20% (Scott et al. 2012). Other suppliers of farmed tuna to the Japanese market include Japan (≈10,000 MT of Pacific bluefin), Australia (≈7,000 MT of southern bluefin), and Mexico (≈1,000 MT of Pacific bluefin) (Scott et al. 2012). Over 90% of global market demand for bluefin tuna comes from Japan, although important markets are emerging in Europe and the United States (Ottolenghi 2008) (Tzoumas et al. 2010).

Common and market names

Scientific Name	*Thunnus thynnus*
Common Names	Atlantic bluefin tuna Northern bluefin tuna Giant bluefin tuna
United States	**Bluefin tuna** (FDA, 2014)
Japan	When sold as sushi or sashimi: *Maguro* (tuna) *Hon maguro* (real tuna) *Kuro maguro* (black tuna)
United Kingdom	Tunny
Spain	*Atún rojo*
Italy	*Tonno rosso*
Greece	τόνος
France	*Thon rouge*

Product forms

Although small amounts of Mediterranean bluefin tuna are sold to the United States and Europe, the majority of farmed bluefin are destined for the Japanese market, where prices can be exorbitant. Tuna sold in sushi restaurants are sold as sushi or sashimi. At its peak, a single portion of high quality sushi or sashimi can easily sell for $50 to $100 or more in prestigious Japanese restaurants (Longo 2011).

Mediterranean bluefin tuna reaches the Japanese market in two forms: frozen (ultra low –60°C) or fresh-chilled; whole or in loins. Specific cuts of bluefin are highly prized and sold in a variety of forms based on the fat content of the flesh, although seemingly slight imperfections can dramatically affect value. Primary cuts include *akami* (lean), *chu-toro* (medium), and *o-toro* (high fat) (Figure 3).

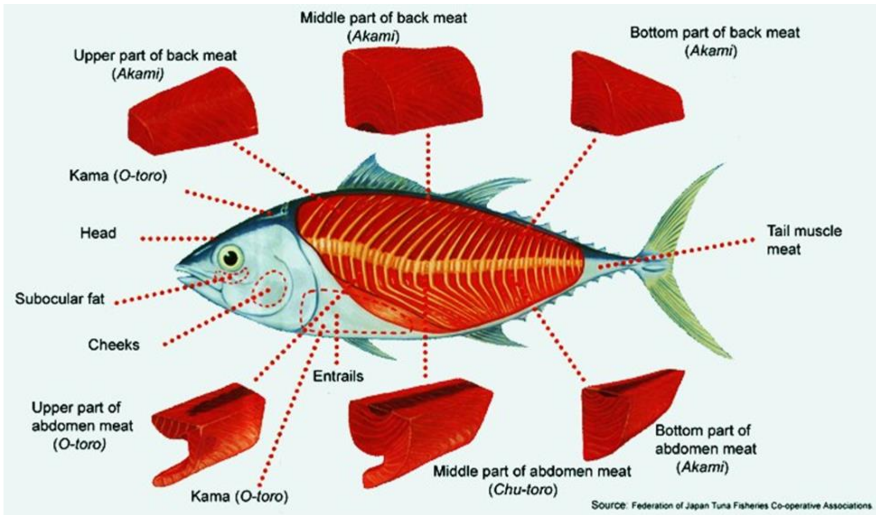

Figure 3. The terms used to describe certain cuts are not specific to bluefin and are applied to all tuna species (Source: Federation of Japan Tuna Fisheries Co-operative Associations).

Analysis

Scoring guide

- With the exception of the exceptional factors (9x and 10X), all scores result in a zero to ten final score for the criterion and the overall final rank. A zero score indicates poor performance, while a score of ten indicates high performance. In contrast, the two exceptional factors result in negative scores from zero to minus ten, and in these cases zero indicates no negative impact.
- The full Seafood Watch Aquaculture Criteria that the following scores relate to are available here http://www.montereybayaquarium.org/cr/cr_seafoodwatch/content/media/MBA_SeafoodWatch_AquacultureCriteraMethodology.pdf
- The full data values and scoring calculations are available in Appendix 1

This Seafood Watch assessment involves a number of different criteria covering impacts associated with effluent, habitats, wildlife and predator interactions, chemical use, feed production, escapes, introduction of non-native organisms (other than the farmed species), disease, the source stock, and general data availability.[1] As a result of the controversy and polarity of opinions relating to some of these aspects, this report has been reviewed by a number of experts representing a variety of stakeholders. In this Mediterranean assessment, Croatia, Cyprus, Greece, Italy, Malta, Spain, Tunisia, and Turkey are used as reference countries for bluefin tuna farming regulatory and management criteria.

[1] The full Seafood Watch aquaculture criteria are available at: http://www.seafoodwatch.org/seafood-recommendations/our-standards

Criterion 1: Data quality and availability

Impact, unit of sustainability and principle

- *Impact: poor data quality and availability limits the ability to assess and understand the impacts of aquaculture production. It also does not enable informed choices for seafood purchasers, nor enable businesses to be held accountable for their impacts.*
- *Sustainability unit: the ability to make a robust sustainability assessment*
- *Principle: robust and up-to-date information on production practices and their impacts is available to relevant stakeholders.*

Data Category	Relevance (Y/N)	Data Quality	Score (0-10)
Industry or production statistics	Yes	2.5	2.5
Effluent	Yes	7.5	7.5
Locations/habitats	Yes	7.5	7.5
Predators and wildlife	Yes	2.5	2.5
Chemical use	Yes	7.5	7.5
Feed	Yes	7.5	7.5
Escapes, animal movements	Yes	7.5	7.5
Disease	Yes	2.5	2.5
Source of stock	Yes	10	10
Other – (e.g. GHG emissions)	No	Not relevant	n/a
Total			**55**

C1 Data Final Score	**6.11**	**YELLOW**

Brief Summary

At the farm level, production data from farmers are scarce and rearing conditions are often treated by many farmers as confidential. Furthermore, bluefin production reporting to international regulatory agencies is highly variable, and scientific interest often focuses more on the economic aspects of farmed tunas than related environmental impacts. At the national level, there is limited access to regulatory data and information on wildlife interactions and disease interactions, and escape statistics are rarely available. Although some laws and regulations in the Mediterranean relevant to bluefin tuna farming are still under elaboration, the environmental impacts of tuna farming within the European Union (EU) are currently regulated and managed using a variety of European Commission (EC) directives and international conventions. Although the framework for these regional regulations is widely accessible, limited details or gaps in publicly available data exist in some key areas for bluefin tuna farming. Overall, due to the relatively new establishment of tuna farming legislation and the lack of publicly available regulatory data in some Mediterranean countries (especially non-EU members), data availability to assess the Mediterranean bluefin tuna farming industry's operations and impacts is considered to be moderate. The Criterion 1 - Data score is 6.11 out of 10.

Justification of Ranking

Key public sources of information or data include:

- Food and Agriculture Organization of the United Nations (FAO)
  - General Fisheries Commission for the Mediterranean Committee on Aquaculture (GFCM-CAQ) Recommendations and Reports to ICCAT http://www.fao.org/fishery/topic/16100/en
  - Fisheries Global Information System for global aquaculture production statistics http://www.fao.org/fishery/statistics/global-aquaculture-production/query/en
  - FAO Fisheries and Aquaculture Technical Papers http://www.fao.org/fishery/publications/technical-papers/en
  - FAO Fisheries and Aquaculture proceedings generally present results and outcomes of technical meetings including national and regional review studies and main findings/recommendations from the meeting discussions. http://www.fao.org/fishery/topic/166293/en
- International Commission for the Conservation of Atlantic Tunas (ICCAT)
  - Standing Committee on Research and Statistics (SCRS) biennial reports on catch statistics and management recommendations http://www.iccat.int/en/pubs_biennial.htm
  - ICCAT Record of bluefin tuna farming Facilities for active operations and farming capacity in the Mediterranean http://www.iccat.int/en/ffb.asp
- European Commission (EC)
  - European Union (EU) aquaculture policy and Directives http://ec.europa.eu/fisheries/cfp/aquaculture/index_en.htm
  - Implementation of the Marine Strategy Framework Directive http://ec.europa.eu/environment/marine/eu-coast-and-marine-policy/marine-strategy-framework-directive/index_en.htm
- EuroStat - EU Aquaculture production http://epp.eurostat.ec.europa.eu/portal/page/portal/fisheries/data/database
- International Union for Conservation of Nature (IUCN), bluefin tuna http://www.iucnredlist.org/details/21860/0
- International Seafood Sustainability Foundation, Tuna Stock Status Update - 2015 http://iss-foundation.org/resources/downloads/?did=564
- National Oceanic and Atmospheric Administration (NOAA), bluefin tuna http://www.nmfs.noaa.gov/pr/species/fish/bluefintuna.htm

Studies and reports by GFCM (FAO) and SCRS (ICCAT) are particularly important data sources for the environmental impacts of bluefin tuna farming and related management measures. Although these organizations provide extensive information at the international level, data can be limited by restrictions on data accessibility at the local level and especially at the farm level.

Mediterranean production statistics are available through FAO FIGIS and EC Eurostat, but current figures from several countries are either limited or absent altogether due to missing data or potential reporting errors. A variety of literature is available on the environmental impacts of discharged waste from bluefin tuna farms, but access to data on industry compliance with effluent regulations or penalties for infringements is limited. Data on benthic impacts are also widely available, but variations in monitoring standards and a lack of transparency in the enforcement process results in limited access to management data. Although the literature and industry experts report that no chemicals are used during the bluefin production cycle, very little monitoring data is available. Baitfish species used by the industry are widely reported in the literature; however, there is limited information on the origin of the baitfish used to feed farmed bluefin tuna. Some information on tuna escapes and diseases is currently available, but these issues have not presented major challenges to the industry, so smaller amounts of information on these subjects are expected. Furthermore, the source of farmed stock for tuna farming in the Mediterranean is well documented as being fully reliant on the capture of wild individuals. Currently, little data exist regarding wildlife interactions between predators and bluefin tuna operations. Data availability on the potential for escapes of unintentionally introduced species is considered relatively good, where reports indicate a moderate risk of pathogen transmission through the use of imported baitfish.

Public disclosure

Public disclosure of regulatory data is widely required in EC legislation, but implementation of the requirement is inconsistent between EU nations.

Public access to the environmental impact assessment process (EIA) for aquaculture, including bluefin tuna farming, is a specific and compulsory requirement in EC guidance material. But the literature shows that, with few notable exceptions, transparency in these assessments is limited (Telfer et al. 2009). In practice, there is limited access to regulatory data, with especially poor levels of publicly available data in Greece and Italy (Telfer et al. 2009) (Karakassis 2013). In Tunisia, maintaining publicly available EIA and monitoring records is not practiced at all (Ahmad and Wood 2002).

Farm-level data

At the farm level, data from farmers are scarce, in that production data are not only variable but are often restricted by farmers. The total tuna production generated by the farming industry is difficult to calculate because the initial net pen stocking information (i.e., biomass and fish size) is only a rough estimate, and any weight gain or FCR value is generally kept confidential by farmers (Ottolenghi 2008). Furthermore, a review of the literature produced growth rates ranging from –6% up to 289%, raising questions concerning the tuna biomass being reported by farmers (Trápaga et al. 2013). Under current farming conditions, growth, food intake, and feed conversion ratios have yet to be accurately established because the high production costs involved do not encourage farmers to risk additional tuna losses by permitting handling-induced stress; this has historically limited research opportunities because of the financial risk (Giménez et al. 2006). From a regulatory perspective, without the ability to obtain accurate data on the initial size and weight composition of the tuna, the FCR and growth rates observed during the rearing phase are not considered robust (Aguado-Giménez and García-García 2005) (Mylonas et al. 2010).

With tuna farmers frequently restricting information, the precise composition of feed fish used in bluefin tuna farming is largely unknown in most cases. Given the commercial nature of bluefin tuna farming, it is expected that each company uses its own (and confidential) feed species composition based on prices in the global market, as well as the results achieved over the farm's tenure (GFCM 2005).

Quality and availability of scientific literature
Scientific interest in tuna farming is increasing, as documented by the growing inventory of scientific papers, but it focuses more on the economic aspects of farmed tunas (e.g., growth conditions, fattening efficiency, and meat contamination) than related environmental impacts (Vizzini and Mazzola 2012).

Remaining data limitations in the Mediterranean include:
- Regional impacts of bluefin tuna farming
- Control measures for farm site maintenance and offal disposal at harvest
- Penalties for regulatory infringements
- Predator interactions/mortality data
- Escape data
- Disease transfer between farm stock and wild counterparts

Data Criterion — Conclusions and Final Score
Overall, data accessibility and availability for Mediterranean bluefin tuna farming is variable depending on the subject matter, and is scored moderately based on current information availability. The final score for the Data Criterion is 6.11 out of 10.

Criterion 2: Effluent

Impact, unit of sustainability and principle

- *Impact: aquaculture species, production systems and management methods vary in the amount of waste produced and discharged per unit of production. The combined discharge of farms, groups of farms or industries contributes to local and regional nutrient loads.*
- *Sustainability unit: the carrying or assimilative capacity of the local and regional receiving waters beyond the farm or its allowable zone of effect.*
- *Principle: aquaculture operations minimize or avoid the production and discharge of wastes at the farm level in combination with an effective management or regulatory system to control the location, scale and cumulative impacts of the industry's waste discharges beyond the immediate vicinity of the farm.*

Evidence-Based Assessment

C2 Effluent Final Score	5.00	YELLOW

Brief Summary

The Seafood Watch Effluent Criterion considers impacts of farm waste beyond the immediate farm area or outside a regulatory allowable zone of effect. With a substantial amount of studies available on the effluent impacts of tuna farms, the evidence-based assessment option has been applied to evaluate this criterion.

Throughout the farms' history in the Mediterranean, bluefin tuna farms have continued to use net pens and whole baitfish feed as the sole rearing technique. All discharged effluent, consisting of uneaten baitfish and solid/soluble waste, is released untreated from the net pens into the surrounding environment. As a result, effluent waste has been detected at considerable distances from farm sites (3 km in some instances). Tuna farming is expected to have an overall greater environmental impact than that of traditional Mediterranean farmed species due to a comparatively higher eFCR and higher waste outputs; however, the seasonal fallow period and dispersive nature of farm sites typically results in few significant impacts reported beyond the immediate farm area. The majority of studies indicate that bluefin tuna farms have little impact on water quality, and the overall benthic impacts are minor and fairly confined in space due to the diffusion and dilution of waste beyond the immediate vicinity of the farm, at dispersive sites. In combination with the decreasing size of the industry, this pattern of localized impact and weak dispersal of particulate waste results in a low potential for cumulative impacts between dispersed individual farm sites or from the industry as a whole. Whereas only minor impacts exist beyond the immediate farm location for dispersive farming sites, depositional locations can produce significant benthic impacts. Furthermore, although the regional impact of bluefin tuna farming is unlikely to cause severe changes in the overall nutrient loading status of the Mediterranean Sea, European Commission regulatory controls for both site-specific and cumulative impacts lack robust measures for waste management. Overall, the lack of significant impacts beyond the immediate farm area combined with ongoing uncertainties regarding the regulation of both site-specific and cumulative impacts results in a low-moderate Effluent Criterion score of 5 out of 10.

Justification of Ranking

The Seafood Watch criteria assess the environmental impacts from waste discharged by Mediterranean bluefin tuna farms in both the Effluent and Habitat Criteria as follows:

- This Effluent Criterion (C2) assesses impacts of both particulate and soluble wastes beyond the immediate farm area or a regulatory allowable zone of effect (AZE).
- The following Habitat Criterion (C3) assesses the impacts of primarily particulate wastes directly under the farm and within a regulatory AZE.

Though the two criteria cover different impact locations, there is inevitably some overlap between them in terms of monitoring data and scientific studies. The majority of this information will be presented in this Effluent Criterion, with the intent of minimizing (but not entirely avoiding) replication in the Habitat Criterion.

Effluent production and dispersal

Organic waste is discharged by bluefin tuna farms in the form of soluble waste, particulate waste, and uneaten baitfish feed. The amount of waste generated by bluefin tuna farming differs by country, as well as between operations in the same country, and is dependent on several factors:

1. Feeding regime
   Bluefin tuna are either fed to satiation 1–3 times a day, 5–6 days a week (Mourente and Tocher 2009) or allotted a daily ration of ≈2%–10% of body weight (Mylonas et al. 2010)
2. Feed-fish species composition
   Composition is dependent on seasonal availability and cost (Mylonas et al. 2010)
3. Farming period
   Adult fattening vs. juvenile rearing (Mylonas et al. 2010)
4. Water temperature
   Seasonal variability affecting metabolism (Mylonas et al. 2010)
5. Fish size at capture
   Adult vs. juvenile growth rates (Trápaga et al. 2013)
6. Initial condition of the fish
   Pre-spawn vs. post-spawn condition of mature tuna (Trápaga et al. 2013)
7. Harvest frequency
   Harvests reduce fish biomass and therefore waste production at farm sites or between cages (Galaz, 2012)

To reduce the volume of organic waste released into the surrounding environment, there have been proposals to integrate polyculture and engineered waste-retention systems (i.e., net pen "diapers" or waste traps) for southern bluefin tuna *(Thunnus maccoyii)* farming in Australia

(Fernandes et al. 2007), but there is currently no mitigation strategy for organic waste discharged by bluefin tuna farms in the Mediterranean. Currently, the only environmental management strategy in place to reduce the impact of discharged waste is fallowing, alongside appropriate siting requirements (currents, water temperature, oxygenation).

As a consequence of partial endothermy and a high metabolic rate (required for constant and high-speed swimming) in bluefin tuna, only a small fraction (≈5%) of the energy input from feed is used for body growth, and a large amount of effluent is typically produced by tuna farms (Mourente and Tocher 2009). The substantial release of waste from tuna farms is also a product of the lower nutritional value and high proportion of soluble nutrients found in frozen baitfish compared to pelletized feeds. Overall, a very low percentage of nitrogen (5.26%) from feed is retained for growth in farmed tuna (Aguado-Giménez et al. 2006) and the remainder of the nitrogen is released into the water column primarily in dissolved and, to a lesser extent, particulate form (Vizzini and Mazzola 2012).

As a percentage of ingested feed, on average, 88.5% of the nitrogen and 38.9% of the phosphorus is excreted through soluble waste. Particulate waste is characterized by an output of 6.3% and 52.9% nitrogen and phosphorus, respectively (Aguado-Giménez et al. 2006). All of these dissolved nutrients are available for uptake by phytoplankton and macroalgae (i.e., seaweeds) for farms located in shallow or protected areas.

In the Mediterranean, 55 authorized bluefin tuna farms occupy a combined physical area ranging from 0.6 km^2 to 1.3 km^2 (based on a stocking density of 3 kg/m^3, a net pen depth of 15–30 m, and the total bluefin tuna farming capacity listed by ICCAT). This footprint can safely be considered relatively small compared to the total marine area of the Mediterranean Sea. Waste inputs from all finfish farms in the region, including those for bluefin tuna, represent less than 5% of the total annual anthropogenic discharge into the Mediterranean and produce an overall annual waste increase of less than 0.01% (Karakassis et al. 2005). Taken as a whole, the regional effect of fish farms is unlikely to cause severe changes in the overall nutrient loading status of the Mediterranean, although local impacts cannot be discounted.

Complex waste dispersion

It should also be noted that the fate of organic waste at fish farms is complex and undertakes multiple pathways. Environmental impacts deriving from the release of organic waste depends upon the farming location and the nature of the receiving water body, in terms of ecological context and site-specific hydrogeographic characteristics. A large percentage of particulate waste released from net pens may be consumed before settling or accumulating on the seafloor. Scavenger feeding of particulate fecal matter, uneaten baitfish, and discarded offal by opportunistic demersal and benthopelagic fish can reduce the biodeposition surrounding bluefin tuna farms (Vizzini and Mazzola 2012). As a result, the major source of waste in the sediments next to tuna farms was recognized to be feces (73%–89%) in comparison to uneaten feed (Vizzini and Mazzola 2012). In addition to these biological attributes, the hydrodynamic regime (current speed, wave action) and geographic exposure (water depth, distance from shore) of bluefin tuna farm sites largely controls the dispersion of organic material (Axiak et al.

2002) (Aksu et al. 2010) (Grigorakis and Rigos 2011). An erosional site characterized by high-flow water currents diffuses waste, and a depositional or low-flow area concentrates them.

Water column impacts

A potentially substantial environmental impact is associated with bluefin tuna farming because of the large biomass reared at each farm site, a high feed conversion ratio, and a feed composition aimed at reaching elevated fat content; however, studies have shown that organic impacts are less intense than generally expected (Vezzulli et al. 2008) (Aksu et al. 2010) (Grigorakis and Rigos 2011). Because of the exposed nature of net pen sites and the uptake of nutrients in the water column, bluefin tuna farms (including those in the Mediterranean) typically do not produce significant effects on the chemistry of the water column (Axiak et al. 2002) (Vezzulli et al. 2008) (Aksu et al. 2010) (Vizzini and Mazzola 2012) (Scott et al. 2012), and nutrient concentrations at monitoring stations up to 500 m away remain comparable to those at control sites (Aksu et al. 2010).

Benthic impacts

The farming of traditional Mediterranean species, such as seabass and seabream, has shown that waste accumulates in the sediments over a wide area, but the extent of benthic impacts surrounding tuna farms is relatively limited in space and intensity (Agius et al. 2006) (Vizzini and Mazzola 2012). Using macrofaunal community parameters, reports indicate that the impact of tuna farming is limited to the area directly underneath the net pens (Sanz-Lázaro and Marin 2008) (Scott et al. 2012) or is restricted to a distance of a few meters to tens of meters in both Mediterranean and Australian tuna farms (Vizzini and Mazzola 2012). Although the dispersal of farm waste has been shown to be responsible for detectable increases in nitrogen levels in *Posidonia* seagrass at large distances (3 km) from a tuna farm, the elevated levels produced no changes in meadow structure and only minor changes to the seagrass community (Ruiz et al. 2010). Closer to the farm, if based on indicators for the European Water Framework Directive, benthic impacts up to 250 m from the farm site were considered insignificant because the majority of samples maintained Good Ecological Status (Moraitis et al. 2013). This low biodeposition may be due to the high solubility of tuna feces and the subsequent diffusion and dilution of large amounts of waste in the water column before settling to the seafloor (Vita et al. 2004) (Vizzini and Mazzola 2012). In addition, the short stocking periods and subsequent fallowing (for tuna fattening farms) at sites with erosional conditions present minor benthic impacts that are largely reversible in nature. Nevertheless, the potential for minor changes to the seagrass community at distances of 3 km from farm sites indicates that there is some risk of more significant impacts at distances closer to the farms.

For example, over a 6-year period (2000–2006), the results of an environmental monitoring study on tuna farming operations revealed a consistent pattern of localized adverse impact on the seafloor during a typical farming season (Holmer et al. 2008). Similarly, a more recent study (Mangion et al. 2014) documented a significant increase in sediment organic carbon spanning a 200 m distance. The magnitude and spatial extent of the benthic impact in both of these studies was attributed to a consistent overfeeding policy at the study site, which allowed for the accumulation of uneaten baitfish feed on the seafloor regardless of siting in a high-energy, erosional environment (Holmer et al. 2008) (Mangion et al. 2014).

Erosional farm sites are associated with an extensive or complete recovery of benthic macrofauna and sediment chemistry to background levels during fallow periods (Sanz-Lázaro and Marin 2008), but significant impacts to the seafloor have been observed at depositional farm sites. In protected areas characterized by shallow depths and slow currents, a high impact zone extending 35 m from the net pens was populated with high densities of opportunistic species, followed by a moderate impact zone extending 220 m (Vita and Marin 2007). Furthermore, significant decreases in *Posidonia* seagrass density and intensive coral bleaching (300 m away from farm sites) are strongly associated with juvenile rearing farm sites in shallow, inshore (i.e., depositional) locations (Požar-Domac et al. 2004) (Požar-Domac et al. 2005) (Kružić and Požar-Domac 2007) (Kružić et al. 2014). Largely controlled by hydrogeographic features, these impacts provide support for the importance of site selection in tuna farming.

Overall, available studies indicate that bluefin tuna farms are not considered to produce significant impacts to water quality or benthic environments beyond the immediate farm area at the majority of sites, and impacts are only considered likely to be significant at locations with depositional characteristics; however, the feeding regime employed at each farm site influences the magnitude and extent of those benthic impacts. Nevertheless, the evidence of community changes at 3 km indicates some ongoing concern. Despite the significant benthic habitat impacts below any one depositional farm site, the potential for cumulative impacts from adjacent sites or from the industry's total impact area is low. Although progressive slaughtering (reducing waste production during the farming period), seasonal fallowing (for fattening farms), and comparatively low stocking densities (2–4 kg m^{-3}) contribute to the general lack of impact in areas beyond the immediate vicinity of the farm site (Mylonas et al. 2010), occasional impacts beyond the immediate vicinity (> 30 m) have been shown to occur in sheltered locations.

Effluent management and regulatory effectiveness in the Mediterranean

Regionally, the environmental impacts of marine aquaculture within the EU are regulated and managed by a variety of EC Directives and International Conventions. There are over fifty EC directives, decisions, and regulations that have an indirect effect on the monitoring and regulation of marine aquaculture (Read and Fernandes 2003). Most aquaculture operations are indirectly regulated by national legislation that is based on these EU Directives. State legislation relevant to limiting the environmental effects of aquaculture is not well established in comparison to capture fisheries, and many of the laws and regulations are so recent that they have yet to produce any significant history of application or enforcement. The primary Directives relevant to bluefin tuna farming include:

1. Water Framework Directive (2000/60/EC)
   The WFD applies to inland and coastal waters up to 1 nautical mile from the coastal State, and aims to protect and enhance all surface waters and groundwater so that they reach a good environmental status (GES) by 2015. The WFD applies GES to individual water bodies, whereas the Marine Strategic Framework Directive (MSFD) is at the regional scale. The WFD uses environmental quality standards (EQS) to address environmental impacts produced by aquaculture, including bluefin tuna farms.
2. Marine Strategic Framework Directive (2008/56/EC)
   The MSFD applies to marine waters, including the coastal waters covered by the WFD, and extends to the boundary of the exclusive economic zone (EEZ) (200 nm from shore). Using 11 quality descriptors, the MSFD requires Member-States to assess the initial state of their marine environments and to develop a definition of good environmental status (GES) with the overall objective of maintaining or achieving GES by 2020 (European Commission 2012). As of December 2013, all but a few Member States have completed the ambition-setting phase of MSFD implementation and identified environmental baselines to establish strategies to reach GES (European Commission 2014). Aquaculture, including bluefin tuna farming, is an environmental pressure addressed in the baseline assessments performed by Member States (European Commission 2012). In reviewing MSFD submissions, the EC has found that many of the definitions of GES often fail to account for existing obligations and standards, and lack coherence across the EU, even between neighboring countries managing the same marine region (European Commission 2014). As of 2014, the MSFD has yet to be implemented among EU nations.
3. Habitats Directive (92/43/EEC)
   The Habitats Directive requires Member States to establish a general system of protection for all naturally occurring plant and animal species listed in the directive's Annex IV. Protected species relevant to bluefin tuna aquaculture are *Posidonia* seagrass *(Posidonia oceanica)* and maerl coralline red algae *(Phymatolithon calcareum* and *Lithothamnion corallioides)*.
4. Strategic Environmental Assessment Directive (2001/42/EC)
   Strategic environmental assessment (SEA) is a relatively new concept and aims to fill the gap between single project developments and the cumulative affects resulting from large or multi-expansion plans or programs. Whereas an EIA generally considers the environmental implications of individual development activities, an SEA considers development plans on a larger, regional scale. Currently, performing an SEA is not a requirement for aquaculture development in the EU (Telfer et al. 2009).
5. Environmental Impact Assessment (EIA) Directive (85/337/EEC)
   The EIA Directive distinguishes between development projects that require a mandatory EIA (Annex I projects) and those where the need for an EIA is dependent on the EC screening criteria implemented by Member States (Annex II projects). Intensive finfish culture, such as bluefin tuna farming, is listed under Annex II. There is variable implementation of the EIA Directive in national legislation: some countries specifically refer to aquaculture while others do not (Telfer et al. 2009). An EIA outlines procedural

requirements but does not establish obligatory environmental standards (European Commission 2012).

In addition to EU Directives, General Fisheries Commission for the Mediterranean Committee on Aquaculture (GFCM-CAQ) of the Food and Agriculture Organization of the United Nations (FAO) assists in coordinating efforts by Mediterranean governments to manage bluefin tuna aquaculture, and has the authority to adopt binding recommendations for its management in the Mediterranean. The GFCM-CAQ has a Working Group on Site Selection and Carrying Capacity (WGSC) that is developing monitoring standards and pushing for the creation of allocated zones for aquaculture (AZAs) for bluefin tuna farming. All bluefin tuna farming nations are members of the GFCM.

These directives and international agreements are implemented at the State level. Member-States must comply with EU mandates, but non-EU nations (i.e., Libya, Morocco, Tunisia, and Turkey) manage the environmental impacts of bluefin tuna farming using their own systems of aquaculture regulations. In countries with less developed environmental regulatory systems, such as Tunisia, there can be a general lack of enforcement and compliance with aquaculture legislation (Ahmad and Wood 2002).

Monitoring requirements

Environmental impact monitoring is required by the EIA Directive to assess environmental impacts (Telfer et al. 2009). Required baseline surveys of water characteristics include physical parameters (temperature and salinity profiles, water transparency), chemical parameters (oxygen tension, pH, ammonia, total nitrogen and phosphorus, silicate), and biological parameters (phytoplankton, chlorophyll, zooplankton, benthic fauna).

State implementation of these monitoring requirements differs between countries in terms of their content and standards (GFCM 2011b) (Karakassis et al. 2013). Although monitoring is mandatory for bluefin tuna farming in all eight nations sampled for this assessment (GFCM 2005) (NASO 2005), only Malta compares monitoring results to site specific limits (Katavić et al. 2005) (Cyprus 2008) (Telfer et al. 2009) (GFCM 2011b) (Scott et al. 2012) (Karakassis et al. 2013). According to EIA Directive requirements, baseline surveys of water and benthic characteristics are used with subsequent monitoring results to assess site characteristics before and after operations begin, in order to restore significantly affected parameters to acceptable levels. But in practice, farm effluent monitoring is more frequently used to assess farm sites against non-specific environmental quality standards. Across the Mediterranean, the definition, procedures, and applicability of monitoring requirements vary greatly between countries and are generally not site-specific (Telfer et al. 2009) (Karakassis et al. 2013).

Posidonia oceanica is a seagrass species that is highly sensitive to aquaculture waste products. It is employed in Malta and Cyprus to determine baseline conditions, in addition to serving as an indicator of nutrient enrichment (Holmer et al. 2008). In Spain, no criteria or objectives are clearly defined to evaluate and track the impacts of aquaculture, leading to a situation where offices for different Spanish regions use different criteria (Telfer et al. 2009). Despite common

EU legislation for implementation of the EIA process, execution of the Directive within different EU countries is inconsistent and often depends on existing and sometimes highly bureaucratic frameworks (Telfer et al. 2009). Consequently, poor implementation has led to inconsistent monitoring standards for bluefin tuna farms throughout the Mediterranean region.

Determining carrying capacity is a relatively well-established practice for net pen aquaculture in northern Europe (e.g., Atlantic salmon), but the current modeling of carrying capacity in the Mediterranean is still at an early stage (Scott et al. 2012). Effluent indicators for carrying capacity are applied by only a few countries, with most relying on regional indices or EQS (Holmer et al. 2008). In the literature, Cyprus, Greece, Malta, and Spain appear to be the only countries with carrying capacity standards for finfish farming (Telfer et al. 2009) (GFCM 2011b) (Scott et al. 2012) (Karakassis et al. 2013). Despite this, the current system in Malta lacks clear guidance on what constitutes an adverse impact, what area an AZE should encompass, and generally fails to give any real guidance on carrying capacity (Scott et al. 2012). In Greece, no models or other predictive methods were given for estimating the carrying capacity of their national marine waters (Karakassis et al. 2013), and a similar situation exists in Spain (Telfer et al. 2009).

Public participation and transparency are widely required in EIA and environmental monitoring program (EMP) legislation, but studies indicate a lack of available data on environmental monitoring for aquaculture activities. In addition to the near absence of published aquaculture monitoring reports in the Mediterranean (FAO 2006), all eight nations sampled for this assessment prohibit public access to monitoring data from bluefin tuna farms.

In Malta, the private environmental firm contracted by the Maltese government to perform all monitoring requirements for the nation's eight tuna farm sites does not publicly disclose monitoring data (pers. comm., Ecoserv scientific consultant 2014**)**. Croatian aquaculture policy states that public access and participation are expected in the monitoring process (Katavić et al. 2005), but other reports suggest that these guidelines apply only to satisfy the form and that the public is marginalized on a regular basis (Vujanic 2010). In Greece, the dissemination of physiochemical parameters by fish farmers is considered inadequate (Telfer et al. 2009), and information on indicators and monitoring schemes is not available in Cyprus (Cyprus 2008). There is poor public involvement in the regulatory process for marine aquaculture in Italy (Telfer et al. 2009) and, in Tunisia, there are no official requirements for impact monitoring and public participation is not practiced at all (Ahmad and Wood 2002) (Economic Commission for Africa 2005).

In addition to the poor availability of monitoring results for Mediterranean aquaculture, insufficient regulatory enforcement has resulted in variable compliance with EMP limits. Monitoring enforcement in Malta is currently considered to be weak (Scott et al. 2012), and in Tunisia, few industrial establishments have been closed by environmental enforcement agencies, because it is unusual for authorities to act in response to unsatisfactory monitoring results in that country (Economic Commission for Africa, 2005). Although monitoring measures in Croatia are binding once an EIA is approved, these measures are often disobeyed (Katavić et al. 2005). In Italy, the absence of any national legislative framework for environmental impact assessment has reduced the effectiveness of environmental assessment as a whole (Telfer et al. 2009).

Regulating cumulative impacts

Although cumulative and long-term impacts are explicitly mentioned in the EIA Directive, an EIA primarily influences a development's individual impacts. In 2003, the EC published a report on the application and effectiveness of the EIA Directive and concluded that there was insufficient consideration of the cumulative impacts of projects (Telfer et al. 2009).

At the European level, the SEA Directive is used to fill the gap between single-project developments and the cumulative effects resulting from multiple developments. FAO reports indicate that an SEA had yet to be a requirement for aquaculture development in 2009, and one is rarely performed today (Telfer et al. 2009) (Karakassis 2013).

Despite the lack of European-level legislation addressing the cumulative impacts of aquaculture, all countries sampled for this assessment possess individual State or local guidelines for site selection (GFCM 2011b) (Scott et al. 2012). Several nations, such as Cyprus and Malta, have for years adopted distance limits (from the coastline and between farms) for tuna farming. Since 2002, bluefin tuna farms in Spain have been required to operate over 6 km offshore (GFCM 2005). Similar legislation has also been introduced in Greece and Turkey (GFCM 2011b). In addition to distance limits, there is a collective effort among tuna farming nations to manage cumulative impacts by designating allocated zones for aquaculture (AZA).

Typically located at highly exposed sites, regulated AZAs are common in several countries under different names (e.g., mixing zone, allowed zone of effect, local impact zone, aquaculture management areas, or Zone A). AZAs specific to bluefin tuna farming are implemented in several countries, including Croatia, Cyprus, Malta, Spain, and Turkey (GFCM 2005) (GFCM 2011a). In an effort to organize EQS reference points, monitoring requirements, and carrying capacity standards for State AZAs, the GFCM's Working Group on Site Selection and Carrying Capacity (WGSC) and the CAQ have been actively pushing for the adoption of AZA legislation at the EU level since 2011 (GFCM 2013) (Karakassis 2013) (GFCM 2014).

Shrinking industry size

As a direct result of the Mediterranean Sea and Eastern Atlantic Ocean Bluefin Tuna Recovery Plan, the bluefin tuna industry has seen a reduction in size since 2008. These recovery measures have forced many bluefin tuna farmers to cease operations, and future industry development leans toward a further reduction in capacity. Of the 69 Mediterranean bluefin tuna farms authorized in 2010 (Aksu et al. 2010), only 55 are currently authorized in 2016 (http://www.iccat.int/en/ffb.asp, last accessed 8/2016).

Effluent Criterion—Conclusions and Final Score

Bluefin tuna farms occupy a relatively small physical area compared to the total size of the Mediterranean Sea and, given the declining number of tuna farms in the area, decreasing waste discharges by the industry are likely to continue as farming capacity is reduced by ICCAT Recovery Plan legislation.

Although tuna farming could be expected (due to the high eFCR) to have an overall greater environmental impact than that of traditional Mediterranean species (e.g., seabass and seabream), the use of seasonal fallow periods (in tuna fattening farms) and the typically dispersive nature of farm sites results in few significant impacts beyond the immediate farm area. Nutrient wastes can be detected at low levels at considerable distances from tuna farms, but the majority of studies indicate that bluefin tuna farms do not significantly impact water quality, and the overall benthic impacts are minor and generally confined in space due to the diffusion and dilution of waste beyond the immediate vicinity of the farm. In combination with the decreasing size of the industry, this pattern of localized impact and weak dispersal of particulate waste results in a low potential for cumulative impacts between dispersed individual farm sites or from the industry as a whole. It should be noted that, even though minor impacts beyond the immediate farm area are largely reversible at dispersive farm sites, siting in depositional locations or employing a farming policy based on consistent overfeeding can potentially produce significant benthic impacts.

Regarding waste management, ongoing uncertainties concerning the regulation of both site-specific and cumulative impacts have led to a lack of robust measures for controlling discharged waste in the tuna farming industry. With few tuna farming nations applying site-specific carrying capacity values, Member States currently rely on inconsistent Environmental Quality Standards that have yet to be formalized by the European Commission. Though many Mediterranean countries have instituted distance limits and adopted AZAs specific to tuna farming, regulations for cumulative impacts on a regional scale remain poorly implemented. Overall, these conditions result in a Criterion 2 - Effluent score of 5 out of 10.

Criterion 3: Habitat

Impact, unit of sustainability and principle

- *Impact: Aquaculture farms can be located in a wide variety of aquatic and terrestrial habitat types and have greatly varying levels of impact to both pristine and previously modified habitats and to the critical "ecosystem services" they provide.*
- *Sustainability unit: The ability to maintain the critical ecosystem services relevant to the habitat type.*
- *Principle: aquaculture operations are located at sites, scales and intensities that cumulatively maintain the functionality of ecologically valuable habitats.*

Habitat parameters	Value	Score	
F3.1 Habitat conversion and function		5.00	
F3.2a Content of habitat regulations	3.50		
F3.2b Enforcement of habitat regulations	2.00		
F3.2 Regulatory or management effectiveness score		2.80	
C3 Habitat Final Score		**4.27**	**YELLOW**
Critical?	NO		

Brief Summary

In bluefin tuna farming, the floating net pens have a minimal direct habitat impact, and benthic impacts produced by individual farms are generally limited to an area directly beneath the farm site and only occasionally farther away. Given the relatively confined nature of benthic impacts, the potential for cumulative impacts from adjacent sites or from the industry's total impact area are considered low. Benthic impacts below fattening farms are largely reversible by fallowing, but the presence of captive tuna year-round at juvenile tuna farming sites has caused significant impact to the benthos. For Habitat Conversion and Function (Factor 3.1), the combination of minor or reversible impacts beneath fattening farms and significant losses in habitat functionality at juvenile tuna farms results in a score of 5 out of 10. Although the majority of tuna farming countries have instituted distance limits for farm sites and recently adopted allocated zones for aquaculture (AZA) to manage habitat impacts, variable EIA requirements and poor transparency in regulatory management have contributed to varying levels of farm siting effectiveness in the Mediterranean. Furthermore, national standards for preventing critical habitat damage are regionally inconsistent. For Habitat and Farm Siting Management (Factor 3.2), the mixed level of implementation for habitat regulations and the subsequent development of significant benthic impacts results in a score of 2.8 out of 10. When combined, these conditions result in an overall moderate Criterion 3 - Habitat score of 4.27 out of 10.

Justification of Ranking

Factor 3.1. Habitat conversion and function

In general, intensive fish farming in open systems, such as net pens, generates a localized gradient of organic enrichment beneath the pens and in adjacent sediments as a result of uneaten food and solid waste, and can strongly influence the abundance and diversity of benthic communities.

Currently, 55 active bluefin tuna farms occupy a combined physical area ranging from 0.6 km^2 to 1.3 km^2 (based on a stocking density of 3 kg/m^3, a net pen depth of 15–30 m, and the total bluefin tuna farming capacity listed by ICCAT). This footprint can safely be considered relatively small compared to the total marine area of the Mediterranean Sea. As a whole, the regional effect of marine finfish farming throughout the region is unlikely to cause severe changes to the overall nutrient loading status of the Mediterranean (Karakassis et al. 2005) (Agius et al. 2006). Despite the potential for significant benthic habitat impacts below any single sheltered farm site, the deposition rates of particulate organic matter beneath the net pens are well below the values mentioned for other cultured finfish species (Vita et al. 2004). Combined with the localized nature of benthic impacts (Holmer et al. 2008) and the decreasing number of bluefin tuna farms in the Mediterranean, the overall potential for cumulative impacts from adjacent sites or from the industry's total impact area is considered to be low.

It must be noted that bluefin tuna in the Atlantic spawn in two distinctly separate areas: the Mediterranean Sea and the Gulf of Mexico. Though it is clear that Mediterranean bluefin tuna farms occupy the same area considered to be essential bluefin tuna breeding habitat, there is no evidence to indicate that the physical structure of the net pens themselves would affect wild bluefin tuna's reproductive capability.

Benthic impacts at erosional and depositional sites

As noted in the Effluent Criterion above, particulate waste and uneaten feedfish lead to enhanced nutrient levels and increase sedimentation rates of organic waste on the seabed. Ensuing changes in sediment chemistry can produce changes to macrobenthic communities, but the degree of impact will vary according to the depositional or erosional nature of the farm site. Increasing the nutrients at erosional, or fast-current, sites results in an increase in the abundance and diversity of macrofauna, while decreases in the abundance and diversity of macrofauna are associated with farm sites located in depositional areas. Although the geophysical and hydrodynamic characteristics of a farm site dominate the pattern of waste dispersal in tuna farming, the feeding regime employed at individual farm sites is an operational factor that significantly influences the accumulation of organic waste beneath net pens. A feed management policy consisting of consistent overfeeding can produce impacts regardless of the dispersive nature at erosional sites (Mangion 2014).

Although benthic impacts are expected in the immediate vicinity of bluefin tuna farms (Scott et al. 2012), only slight accumulations of organic matter are recognizable in the sediments beneath erosional farm sites, where high water depth and a strong hydrodynamic regime disperse the waste before it accumulates on the seafloor (Vizzini and Mazzola 2012).

For tuna farms set in depositional locations, the impacts occurring directly beneath the immediate farm site can be profound. Studies in Spain show that benthic alterations in sheltered areas are characterized by a clear increase in organic enrichment, where a high impact zone characterized by elevated densities of opportunistic species ranged from 5 m to 35 m from the net pens, and a moderately stressed zone characterized by a slight change in community structure extended to 220 m (Vita and Marin 2007) (Sanz-Lázaro and Marin 2008). In both studies, the subsequent fallow period produced partial or complete remediation of the benthos next to the AZE, but the organic enrichment footprint was still noticeable directly beneath the net pens.

Juvenile tuna farming

Because of the absence of mature tuna in the Adriatic Sea, the farming technique employed in this region involves the long-term rearing of juvenile bluefin (8–30 kg in body weight) for 1 year to several years. Representing 13% of the total Mediterranean bluefin tuna farming capacity (http://www.iccat.int/en/ffb.asp, last accessed 8/2016), juvenile tuna farming is classified by ICCAT separately from tuna fattening, primarily for the difference in the size of the fish at capture and a prolonged farming period (years instead of months) (ICCAT 2008). Employed exclusively by Croatian tuna farmers, juvenile farm net pen sites in the Adriatic are continuously stocked with tuna, creating production cycles with a rolling 2–3 year overlap (Mylonas et al. 2010). A Croatian study found that, without a seasonal fallow period between production cycles, juvenile-rearing methods resulted in a major loss of functionality to the benthos, in which a sharp decrease in redox-potential was permanent and significantly higher organic carbon and nitrogen concentrations were observed in the sediments under the net pens (Matijević et al. 2006) (Matijević et al. 2007).

Minor benthic impacts at erosional sites are largely reversible with fallowing; however, the substantial biodeposition associated with juvenile tuna farming in the Adriatic Sea generates significant damage to the benthic environment, due to the absence of fallow periods between rearing cycles. Furthermore, a feeding strategy involving consistent overfeeding and siting in depositional locations can further amplify the accumulation of particulate organic matter beneath net pens. When combined, these factors result in a moderate Habitat Conversion and Functionality score of 5 out of 10.

Factor 3.2. Habitat and farm siting management effectiveness (appropriate to the scale of the industry)

Although the Effluent and Habitat Criteria cover different impact locations, there is inevitably some overlap between them in terms of regulatory and management effectiveness. For additional information on environmental management and monitoring requirements, see the Effluent Criterion.

Environmental Impact Assessment

The EIA Directive (85/337/EEC) lists intensive finfish culture under Annex II, which authorizes EU Member States to specify what types of intensive finfish aquaculture require an EIA. In addition, the eight nations sampled in this assessment have each established either State or local guidelines for tuna farming, in which the license to establish any farm depends on the results of environmental monitoring and an environmental impact assessment (Economic Commission for Africa 2005) (GFCM 2005) (NASO 2005). Although environmental agencies are required to assess potentially significant environmental impacts of aquaculture projects before a license is given, a variety of regulatory systems are in place and there are rarely any well-defined Ecosystem Quality Standards (EQS) available for comparison with monitoring results (Karakassis et al. 2013). Despite the European Community's attempts to harmonize legislation between EU Member States, EIA requirements still differ from one country to another (Cardia and Lovatelli 2007) (Telfer et al. 2009). EIA procedures exhibit considerable diversity both in terms of methodology and legislative framework, resulting in a general inconsistency regarding their content and the standards required between different countries. The implementation of the EIA Directive into national legislation for bluefin tuna farming is highly variable, and for some Member States, such as Italy, a formal EIA is not required at all under certain conditions (Telfer et al. 2009).

Site selection process

In the Mediterranean, farm siting management is implemented at the State level with guidance from the EC, ICCAT, and the GFCM (GFCM 2011b) (Scott 2012). All countries sampled for this assessment possess individual State or local guidelines for site selection (GFCM 2011b) (Scott et al. 2012). In Spain and Italy, some regions have developed siting regulations on a local basis (e.g., Andalusia, Sicily). Similarly, in Tunisia there are no official standards or guidelines for site selection, but licensing procedures provide some site requirement criteria for marine aquaculture (GFCM 2011b).

In terms of regulatory control for cumulative impacts, as noted in the Effluent Criterion, regulations in the Mediterranean are mandated regionally by the EU and implemented at the State level. Although cumulative and long-term impacts are explicitly mentioned in the EIA Directive, an EIA primarily influences a development's individual impacts. At the European level, the SEA Directive is used to fill the gap between individual aquaculture developments and the cumulative affects resulting from multiple developments. FAO reports indicate that SEAs are rarely performed today (Telfer et al. 2009).

Despite the lack of regulations for cumulative impacts required at the European level, several nations, including Cyprus, Greece, Malta, Spain, and Turkey, have adopted distance limits (from the coastline and between farms) for tuna farming (GFCM 2005). In addition to distance limits, there is a collective effort among tuna farming nations to manage cumulative impacts by designating allocated zones for aquaculture (AZA). Typically located at highly exposed sites, AZAs specific to bluefin tuna farming are common in several Mediterranean countries, including Croatia, Cyprus, Malta, Spain, and Turkey (GFCM 2005) (GFCM 2011a). Since 2011, the GFCM's

WGSC and the CAQ have been actively pushing for the adoption of AZA legislation at the EU-level (Karakassis 2013) (GFCM 2013) (GFCM 2014).

Critical habitat protection

In accordance with the Habitats Directive (92/43/EEC), EU Member States are obligated to avoid environmentally sensitive locations, including those found in marine habitats. Endemic to the Mediterranean, *Posidonia oceanica* seagrass is highly susceptible to changes in organic input and is a major siting concern for tuna farmers under the Habitats Directive. Implemented at the State level, minimum buffer zones for these critical habitats differ across the EU, and the effectiveness of these requirements is inconsistent regionally—e.g., a 600-m buffer zone is required for tuna farms in Italy (GFCM 2005) and an 800-m buffer is required in Cyprus (Agius et al. 2006). Although significant decreases in *Posidonia* density are associated with farm sites in proximity to shallow seagrass areas (Požar-Domac et al. 2004) (Požar-Domac et al. 2005) (Vrgoč 2013) (Kružić et al. 2014), tuna farms are still capable of producing elevated nitrogen signatures in *Posidonia* meadows located at least 3 km from a farm site (Ruiz et al. 2010).

All tuna farming nations in the EU have instituted conservation measures for the protection of critical habitat, but the habitat regulations in some States, such as Greece and Croatia, lack robust requirements to protect *Posidonia* meadows (Požar-Domac et al. 2004) (Karakassis et al. 2013). Non-EU members, such as Turkey, have also banned tuna farms from siting in environmentally sensitive areas, but Tunisia has yet to implement any national standards protecting *Posidonia* seagrass (Telfer et al. 2009) (GFCM 2011b).

For critical habitats that have already sustained damage, the United Nations Convention on Biological Diversity further requires Member States to restore degraded habitats and ecosystem services and to further halt all biodiversity losses entirely by 2020 (European Commission 2012).

The score for Factor 3.2a is 3.5 out of 5.

Regulatory effectiveness and enforcement

In Mediterranean aquaculture, it is difficult to contact relevant environmental management organizations because of a lack of coordinating tools for solving overlapping and concurrence between agencies (GFCM 2011b). Among the 8 nations sampled, there are 64 environmental agencies or authorities involved in granting aquaculture licenses, with as many as 15 agencies in Turkey alone (GFCM 2011b). In contrast, tuna farming countries in North Africa have indicated that inadequate staff, both in numbers and in expertise, has greatly limited effective implementation of environmental regulations. In Tunisia, environmental monitoring is not performed on a systematic basis because of human resource constraints, and any environmental monitoring program (EMP) or regulatory follow-up is often neglected (Economic Commission for Africa 2005).

In addition to the complexity in identifying and contacting environmental agencies, there is also difficultly in publicly accessing regulatory data. Although transparency is widely required in EIA and EMP legislation (Cardia and Lovatelli 2007), there is limited access throughout the EU, with especially poor levels of publicly available data in Greece and Italy (Telfer et al. 2009) (Karakassis 2013). Outside the EU, maintaining publicly available EIA and monitoring records are not practiced in Tunisia (Ahmad and Wood 2002). Given the general absence of published monitoring reports in Mediterranean aquaculture (FAO 2006), the eight nations sampled for this assessment have specifically prohibited public access to monitoring data for bluefin tuna farming (Ahmad and Wood 2002) (Economic Commission for Africa 2005) (Cyprus 2008) (Telfer et al. 2009) (Vujanic 2010) (pers. comm., Ecoserv scientific consultant 2014).

Although EU mandates are intended to simplify the regional application of environmental regulations, the difficulty in contacting relevant environmental agencies and poor transparency in regulatory management have contributed to varying levels of farm siting effectiveness and variable compliance with EMP limits. Aquaculture monitoring in Malta is currently considered to be weak (Scott et al. 2012), and in Tunisia, it is rare for environmental enforcement authorities to act on unsatisfactory monitoring results (Economic Commission for Africa 2005). In Croatia, monitoring measures are often disobeyed (Katavić et al. 2005), and the absence of any national legislative framework for any EIA process in Italy has reduced the effectiveness of environmental review in that country altogether (Telfer et al. 2009).

Overall, the regional application of EU site selection guidelines is poor, but individual Member States are addressing habitat impacts on a local basis by implementing distance limits and AZAs specific to bluefin tuna farming. Although an EIA is required for all bluefin tuna farming nations in this assessment, variable EIA requirements and poor transparency in regulatory management have contributed to varying levels of farm siting effectiveness in the Mediterranean. Furthermore, national standards for preventing critical habitat damage are regionally inconsistent.

The score for Factor 3.2b is 2 out of 5.

Factors 3.2a and 3.2b combine to result in a final score for Factor 3.2 Management Effectiveness of 2.8 out of 10.

Habitat Criterion—Conclusions and Final Score

The final score for the Habitat Criterion is a combination of the habitat conversion score (Factor 3.1) and the effectiveness of the regulatory system in managing potential cumulative impacts (Factor 3.2).

In bluefin tuna farming, benthic impacts are generally restricted to an area directly beneath or in the immediate vicinity of the farm site and only occasionally farther away. Given the relatively confined nature of benthic impacts, the potential for cumulative impacts from adjacent sites or from the industry's total impact area are considered low. Although benthic impacts below fattening farms are largely reversible by fallowing, the presence of captive tuna year-round at juvenile tuna farming sites has been demonstrated to cause significant benthic impacts. Furthermore, the majority of tuna farming countries have instituted distance limits for farm sites and recently implemented appropriate AZAs to regulate habitat impacts, but variable EIA requirements and poor transparency in regulatory management have contributed to varying levels of farm siting effectiveness in the Mediterranean. Additionally, national standards for preventing critical habitat damage are regionally inconsistent. Overall, these conditions result in a low to moderate Criterion 3 - Habitat score of 4.27 out of 10.

Criterion 4: Evidence or Risk of Chemical Use

Impact, unit of sustainability and principle

- *Impact: Improper use of chemical treatments impacts non-target organisms and leads to production losses and human health concerns due to the development of chemical-resistant organisms.*
- *Sustainability unit: non-target organisms in the local or regional environment, presence of pathogens or parasites resistant to important treatments*
- *Principle: aquaculture operations by design, management or regulation avoid the discharge of chemicals toxic to aquatic life, and/or effectively control the frequency, risk of environmental impact and risk to human health of their use*

Chemical Use parameters	Score	
C4 Chemical Use Score	**10.00**	
C4 Chemical Use Final Score	**10.00**	**GREEN**
Critical?	NO	

Brief Summary

Bluefin tuna farming practices currently do not employ pesticides, antibiotics, hormones, or other chemical therapeutants during the production cycle. Copper is used as an antifoulant on aquaculture nets in the production of other species in the region, but there is no literature or data indicating its use in tuna farms, nor is there evidence for significant metal concentrations beneath tuna farms. Overall, the absence of chemical use combined with the lack of evidence for copper-based antifoulant use or benthic impacts result in a low level of concern and a Criterion 4 - Chemical Use score of 10 out of 10.

Justification of Ranking

Though no official monitoring data are available, communication with industry and academic experts indicate that in Mediterranean bluefin tuna farming, no pesticides, antibiotics, hormones, or any other chemical therapeutants are applied at any point in the production cycle (pers. comm., Malta Aquaculture Research Centre 2015) (pers. comm., Spanish Institute of Oceanography 2015) (pers. comm., Hellenic Center for Marine Research 2015). Further, a report by FAO indicates that no antibiotics, hormones, or chemical additives are added to the baitfish feed (GFCM 2005). Although chemicals are not directly applied to the tuna or the feedfish, copper-based antifouling paint may be used, because it is used on capture vessels, tow cages, net pens, and anti-predator nets in other Mediterranean aquaculture operations (Castritsis-Catharios et al. 2014) (Nikolaou et al. 2014) (Cotou et al. 2012).

Despite the use of copper-based antifoulant paints on fish farming equipment throughout the region, there is no literature directly linking tuna farming with copper-based antifoulants or significant metal concentrations in the sediments beneath farm sites. And, prevailing oligotrophic conditions in the Mediterranean have been shown to be largely able to assimilate the inorganic fish farm effluents and to maintain heavy metal concentrations at acceptable levels for the marine ecosystem (Kalantzi et al. 2013).

Currently, little or no other chemical controls exist specifically for bluefin tuna farming, apart from established regulations for other farmed fish species (GFCM 2005). Copper is listed under EU Dangerous Substances legislation and its release into the marine environment may be controlled under national discharge limits. Because ICCAT and the GFCM have recommended avoiding the use of copper, the aquaculture sector at large has actively been searching for alternatives to existing copper-coating products and moving toward more environmentally friendly antifouling methods. Research on alternatives includes natural repellents (biofilms), biological controls (grazers), different coatings (silicon), and nanotechnology applied to new materials (Haroun et al. 2007) (IUCN 2007).

Chemical Criterion—Conclusions and Final Score

Net pen production systems are open to the environment, and accumulation of chemicals in the sediments is possible. Although monitoring data do not exist, extensive anecdotal evidence suggests that no chemicals are applied in bluefin tuna farming in the Mediterranean. In addition, the current lack of chemical use combined with current industry fallowing practices and the hydrogeographic nature of exposed farm sites indicate that the impact of any chemical use would be negligible. For chemical use in Mediterranean bluefin tuna farming, the level of concern is low and results in a score of 10 out of 10.

Criterion 5: Feed

Impact, unit of sustainability and principle

- *Impact: feed consumption, feed type, ingredients used and the net nutritional gains or losses vary dramatically between farmed species and production systems. Producing feeds and their ingredients has complex global ecological impacts, and their efficiency of conversion can result in net food gains, or dramatic net losses of nutrients. Feed use is considered to be one of the defining factors of aquaculture sustainability.*
- *Sustainability unit: the amount and sustainability of wild fish caught for feeding to farmed fish, the global impacts of harvesting or cultivating feed ingredients, and the net nutritional gains or losses from the farming operation.*
- *Principle: aquaculture operations source only sustainable feed ingredients, convert them efficiently and responsibly, and minimize and utilize the non-edible portion of farmed fish.*

Feed parameters	Value	Score	
F5.1a Fish In: Fish Out ratio (FIFO)	20.00	0.00	
F5.1b Source fishery sustainability score		-6.00	
F5.1: Wild Fish Use		0.00	
F5.2a Protein IN	384.00		
F5.2b Protein OUT	18.22		
F5.2: Net Protein Gain or Loss (%)	-95.25	0	
F5.3: Feed Footprint (hectares)	143.04	0	
C5 Feed Final Score		**0.00**	**CRITICAL**
Critical?	YES		

Brief Summary

Mediterranean bluefin tuna farms rely solely on the use of whole wild baitfish for feed. Unlike almost all other aquaculture industries that are focused on growing their farmed stock, the primary goal of the majority of Mediterranean tuna operations is to increase the tuna's fat content for market desirability. Thus, the feed conversion ratio is typically high. Reported economic feed conversion ratios (eFCR) vary from 10–15 for farming juveniles and up to 20–30 for the fattening of adult tuna. The exclusive use of whole feedfish means that the Fish In to Fish Out ratio (FIFO) is the same as the eFCR and produces a critical FIFO score of 0. In the wild, tuna also consume baitfish, but do so as part of a complex natural foodweb and ecosystem. The extraction of these two ecosystem components (i.e., the tuna and the baitfish) and their use as inputs in an artificial farming system does not enable them to provide the same ecosystem services. Sardine, mackerel, and herring represent the most common feed ingredients, but a variety of baitfish species are utilized as feed, and the majority are imported globally from foreign fisheries. A precautionary Source Fishery Sustainability score of –6 out of –10 was applied to Factor 5.1 (Wild Fish Use), producing a final adjusted score that remained 0 out of 10. Furthermore, a net protein loss greater than 90% and the presence of a significant feed footprint (143.04 ha per ton of farmed fish) represent additional environmental concerns. Overall, the absence of by-products and non-edible processing ingredients as alternative sources of feed protein along with the highly inefficient conversion of feed into harvestable fish result in a critical Criterion 5 - Feed score of 0 out of 10.

Justification of Ranking

In the Mediterranean, whole wild baitfish are used as the sole feed source for farmed bluefin tuna (GFCM 2005) (Ottolenghi 2008) (Mourente and Tocher 2009) (Mylonas et al. 2010) (Tzoumas et al. 2010) (Grigorakis and Rigos 2011) (pers. comm., Malta Aquaculture Research Centre 15) (pers. comm., Spanish Institute of Oceanography 2015) (pers. comm., Hellenic Center for Marine Research 2015). Farmed bluefin tuna are purposefully fed a diet made up of fish with high lipid content to increase their fat stores, making them more desirable to the sushi and sashimi markets. Feeding practices have been developed to simultaneously accommodate the tuna's large appetite and minimize the labor required. Feeding activity is typically regulated visually by divers or underwater surveillance to identify when fish are satiated, to determine feed performance, and to estimate feed losses (Ottolenghi 2008) (Mourente and Tocher 2009) (Mylonas et al. 2010). Under these conditions, reports indicate that farmed juvenile tuna can potentially gain weight twice as fast as wild counterparts (Tzoumas et al. 2010).

Wild feedfish are used on an exclusive basis because of a cultural preference in Japan for tuna fattened on non-pelleted feed. Japanese consumers primarily eat tuna meat raw, and flesh quality (i.e., texture and taste) is quite important and varies, depending on the feeding policy used by the farmers (Ottolenghi 2008) (Mourente and Tocher 2009). This negative consumer perception of artificial feeds has made farmers more reluctant to adopt feeding strategies that include pellets (Grigorakis and Rigos 2011). Farmers strongly prefer not to use pellets in order to avoid consumer rejection. Furthermore, studies have shown that eFCR values resulting from a baitfish-based diet and pelleted feeds were quite similar for southern bluefin tuna *(Thunnus maccoyii)* grown in Australia (Webster and Lim 2002) (Fernandes et al. 2007) (Mourente and Tocher 2009). Combined with high feed production costs (Ottolenghi 2008) and difficulty in producing feeds that are readily taken by tuna (Mourente and Tocher 2009), Mediterranean farmers are reluctant to switch to pelleted feed, and they continue to use readily available baitfish fisheries.

Feeding practices

Research regarding feeding frequency has shown that feeding tuna 7 days a week does not result in significantly higher growth rates or better condition factors than a feeding strategy in which the fish are fed 5 or 6 days a week. Thus, most farmers apply a feeding regime in which tuna are fed to satiation 1–3 times a day, 5–6 days a week during the summer growing season, and less so during the winter (Mourente and Tocher 2009). If tuna are not fed to satiation, the daily feed input varies from 2%–10% of the estimated tuna biomass (Ottolenghi 2008), depending on water temperature, fish size at capture, and length of the farming period (Mylonas et al. 2010). These feeding practices differ by country and on a local basis as well.

Feedfish composition
Farmed bluefin tuna are primarily fed a mixed diet composed of a variety of small, pelagic species including round sardinella *(Sardinella aurita)*, pilchard *(Sardina pilchardus)*, herring *(Clupea harengus)*, chub mackerel *(Scomber japonicus)*, horse mackerel (*Trachurus* spp.), bogue *(Boops boops)* and squid (*Illex* spp.) (GFCM 2005) (Ottolenghi 2008). The specific composition of feedfish is not known in most cases because of the commercial nature of the tuna farming industry, and it is expected that each company uses its own feed species composition based on the results achieved over the farm's tenure (GFCM 2005). Information on feed composition is considered proprietary and is generally not available to the public.

Feedfish are occasionally procured locally, but the majority are imported globally from countries outside the Mediterranean (GFCM 2005) (Ottolenghi 2008) (Mourente and Tocher 2009) (Longo 2011) (pers. comm., Malta Aquaculture Research Centre 2015) (pers. comm., Spanish Institute of Oceanography 2015) (pers. comm., Hellenic Center for Marine Research 2015), including Denmark, Holland, the Netherlands, Ireland, South America, and the United States. Baitfish used in Croatia was sourced both from the North Sea and locally in 2001 (Ottolenghi et al. 2004), and Turkish feedfish imports in 2002 originated from Spain, Mauritania, Norway, and the Netherlands (WWF 2005) (GFCM 2005). The rationale behind sourcing baitfish from these distant fisheries derives from the seasonal availability of each species and the cost of shipment from these locations (Mylonas et al. 2010).

Because the baitfish feed composition is based on maximizing the fat content in farmed bluefin tuna, it should be noted that the feeding practices employed by tuna farmers do not reflect the normal food spectrum available to wild bluefin (Ottolenghi 2008). Based on the examination of gut contents, reports indicate that bluefin tuna are opportunistic predators and consume a variety of pelagic baitfish species, crustaceans, and cephalopods, based on prey availability and distribution (Battaglia et al. 2013) (Medina et al. 2015) (Mourente and Tocher 2009). Because prey items are opportunistically consumed during feeding migrations (Chase 2002), the prey composition for wild bluefin is more varied than the feedfish provided by Mediterranean tuna farming operations.

Ecological impact of wild feed
Although the baitfish species used by farmers represent a natural dietary component of wild bluefin, the use of globally sourced wild baitfish for farming is inherently extractive in nature. The sourcing of wild baitfish for farming both increases pressure on local pelagic feedfish resources and creates additional impact on foreign fisheries outside the Atlantic. Removal of both the tuna and baitfish from the wild and concentrating them into tuna farms result in the loss of ecosystem services provided by both species groups throughout their native ranges.

Feed efficiency - Economic feed conversion ratio
An economic feed conversion ratio (eFCR) is used to measure the efficiency of farmed tuna at converting feed into harvestable fish. In the Feed Criterion, an eFCR is used to determine the industry's reliance on wild feedfish, the net protein gain/loss in tuna production, and the ocean area appropriated for feed ingredients.

Although up-to-date commercial eFCR values are typically not available, a range of figures are reported in the literature for farmed bluefin due to several key factors:

1. Inability to accurately quantify biometric data at capture

   Currently, there is no standardized system for determining bluefin tuna growth under net pen culture conditions, since accurate techniques to quantify the weight and size of large, fast-moving live fish remain difficult (Galaz 2012). Furthermore, farmers are extremely averse to tuna handling, because high production costs do not encourage them to risk additional losses by permitting handling-induced stress (Giménez et al. 2006).

2. Farming conditions

   Several siting and operational elements affect feed conversion in bluefin tuna farming. Also reported in the Effluent Criterion, the farming practices that characterize waste production are also closely related to feed conversion:
   - Feeding regime
   - Feedfish species composition
   - Farming period
   - Water temperature
   - Age of the fish at capture

3. Fish size at capture

   Distinctly different eFCR values are observed in bluefin tuna, depending on the size of the fish being farmed. Growth throughout the production cycle for adult tunas under prevalent fattening conditions ranged from 20%–35%, whereas juvenile growth was closer to 80% over the same farming period (Galaz 2012). Although mature tuna gain more weight due to their comparatively larger size, juvenile tuna grow at an overall faster rate and convert feed more efficiently (Aguado-Giménez and García-García 2005) (Tičina et al. 2007) (Galaz 2012) (Hattour and Kouched 2012) (ICCAT 2014). As a result, the eFCR values for juvenile tuna are much lower and range from 10–15:1 over a typical farming season (Aguado-Giménez and García-García 2005) (Ottolenghi 2008) (Mylonas et al. 2010), whereas adult tuna eFCRs range from 10–30:1 (Aguado-Giménez and García-García 2005) (Vezzuli et al. 2008) (Ottolenghi 2008) (Mylonas et al. 2010) (Longo 2011) (Moraitis et al. 2013). Currently, bluefin fattening farms represent 87% of the tuna farming capacity in the Mediterranean (http://www.iccat.int/en/ffb.asp, last accessed 8/2016).

Because the large majority of bluefin farms in the Mediterranean are fattening operations and the industry continues its movement away from rearing juveniles in response to heavily reduced TAC quotas and increased minimum size restrictions (ICCAT 2014), based on the above published literature, an approximate adult tuna eFCR value of 20:1 is used in this assessment to represent the Mediterranean region.

Factor 5.1. Wild Fish Use

This factor combines an estimate of the amount of wild fish used to produce farmed bluefin tuna with the sustainability of the fisheries from which they are sourced.

Using Seafood Watch Criteria, the use of whole, wild baitfish as the only feed input results in a FI:FO value equal to the eFCR for farmed tuna. A FI:FO value of 20 indicates that 20 tons of wild fish are required to supply sufficient feed for 1 ton of farmed tuna growth. The substantial amount of feed input required to produce harvestable farmed tuna results in a Critical FI:FO score of 0.

Source fishery sustainability

Given the variety of baitfish species used in bluefin tuna farming and the global nature of baitfish sourcing, the sustainability of every baitfish fishery contributing to tuna feed throughout the Mediterranean cannot be assessed with any confidence, because the list of species is indeterminate and in constant change. These conditions result in a precautionary score of –6 out of –10 for source fishery sustainability.

Wild Fish Use Score

A sustainability penalty of –6 is applied to the FI:FO score and generates a final Wild Fish Use score of 0 out of 10, indicating critical conservation concerns.

Factor 5.2. Net Protein Gain or Loss

Aquaculture has the potential to be a net producer of protein, but when external feed is used in any significant quantity, there is typically a net loss of protein when feed is converted into farmed fish. A net protein value is quantified using an average protein content of feed, FCR, the protein content of whole harvested tuna, and the edible yield of each fish.

In addition to the eFCR, other values used to calculate the net protein consumption in bluefin tuna farming are:

1. Protein content of feed ingredients

   The specific combination of baitfish used to feed farmed bluefin varies depending on their availability and cost of shipment. The three most commonly used baitfish species (sardine, mackerel, and herring) observed in the literature were used to calculate an average protein content of feed. Based on yield values by FAO (Torry Research Station 1989), an average protein content of 19.2% is applied to baitfish feed. All of these species are considered to be "edible" protein sources.

2. Protein content of harvested tuna

   An average protein content of 21.55% is applied to whole harvested farmed tuna based on sampling data reported from two separate fattening farms in Spain (Giménez-Casalduero and Sánchez-Jerez 2006).

3. Edible yield of harvested tuna

   Based on multiple values, an edible yield of 69.13% is applied to farmed bluefin tuna (Oksuz 2010) (Deguara et al. 2010) (ICCAT 2006).

For farmed tuna, the overall reliance on external feedfish inputs results in a calculated 95% loss in edible protein, and a critical factor score of 0 out of 10 (due to the > 90% net protein loss).

Factor 5.3. Feed Footprint

This factor is an approximate measure of the global resources used to produce feed based on the area used to produce the ingredients.

The resources used to obtain feedfish for tuna farming are substantial, and a large amount of ocean area is required to produce the feed necessary to grow each farmed fish (143.04 ha ton^{-1} of farmed fish). The feed footprint for farmed bluefin tuna is considered very high and results in a factor score of 0.

Feed Criterion—Conclusions and Final Score

The final Feed score combines the three factors with a double weighting on the FI:FO score. An exceptionally high FI:FO value of 20 indicates that bluefin tuna farming (the majority of which are fattening operations) does not increase food production. On average, an estimated 20 tons of wild fish are used to produce 1 ton of farmed bluefin tuna in the Mediterranean. The consequence of this process is a net protein deficit, where > 90% of protein inputs are lost to the environment. The inefficiency of bluefin tuna feed is compounded by the significant ocean area appropriated for feed ingredients, because the industry relies completely on using wild baitfish for feed. Overall, even though bluefin farming in theory mimics the natural predator-prey relationship found in the wild, the highly extractive nature of bluefin tuna farming results in a final Feed Criterion score that is Critical/Red and is scored 0 out of 10.

Criterion 6: Escapes

Impact, unit of sustainability and principle

- *Impact: competition, genetic loss, predation, habitat damage , spawning disruption, and other impacts on wild fish and ecosystems resulting from the escape of native, non-native and/or genetically distinct fish or other unintended species from aquaculture operations*
- *Sustainability unit: affected ecosystems and/or associated wild populations.*
- *Principle: aquaculture operations pose no substantial risk of deleterious effects to wild populations associated with the escape of farmed fish or other unintentionally introduced species.*

Escape parameters	Value	Score	
F6.1 Escape Risk		2.00	
F6.1a Recapture and mortality (%)	0		
F6.1b Invasiveness		10	
C6 Escape Final Score		**10.00**	**GREEN**
Critical?	NO		

Brief Summary

For net pen aquaculture, there is an inherent risk of escape from catastrophic losses or more chronic "leakage." But given that farmed tuna are the product of capture-based aquaculture and that captive tuna originate from the Mediterranean, the risk of ecological impact of escaped tuna on other wild species or wild counterparts is considered to be minimal. The resulting Criterion 6 - Escape score is therefore 10 out of 10.

Justification of Ranking

The Escape Criterion combines the risk of escape with the potential for ecological impact of the escapees. The capture-based nature of bluefin farming in the Mediterranean creates unusual escape dynamics, and inevitably a lower level of concern regarding potential ecological impacts of escapes, as discussed below.

Factor 6.1a. Escape risk

Fish escapes from fish farming sites is an inevitable occurrence resulting from human errors during routine handling, mechanical failures, damages caused by adverse weather conditions, or aquatic predators such as seals and dolphins tearing the nets (Grigorakis and Rigos 2011).

In bluefin tuna farming, operational "leakage" losses are associated with tuna escapes during initial capture, fish transfer between purse seines and transport cages, and during net-herding maneuvers at harvest. Large-scale "event" escapes are typically caused by storms, vandalism, marine mammals, or human error.

Because storm damage is one of the greatest causes of escapes for farmed bluefin tuna, the industry widely uses floating net pens constructed of high density polyethylene (HDPE) tubes that are designed for use in severe offshore weather conditions (Cardia and Lovatelli 2007).

Robust data on escapes are rarely available because of the difficulty in counting live fish and also knowing the proportion of any losses due to mortality versus escapes at harvest. Without robust data on escape statistics, the magnitude of current escapes is unknown, and information on both low-level leakage and large event escapes remains uniformly poor throughout the Mediterranean (Grigorakis and Rigos 2011). Regardless of the absence in escape statistics, the very high biomass held in any one net pen and the risk of escape inherent to net pen farming suggest that the ongoing potential for escapes continues to be high.

Despite improvements in the design and construction of net pens, the risk of escape from catastrophic losses or chronic leakages undeniably remains. The initial numerical Escape Risk factor is scored 2 out of 10.

Recapture and Mortalities

With no specific recapture data available for the Mediterranean, no Recapture and Mortality adjustment was applied to the Escape Risk score.

Factor 6.1b. Invasiveness

Because farm stock consists entirely of wild individuals that are native to the Mediterranean, any significant impact (e.g., competitive and/or genetic) of escaped bluefin tuna on other wild species, including wild counterparts, is unlikely. Although the potential exists for ecological impacts from re-introducing these farmed tuna into their native habitat (i.e., potential pathogen amplification and dispersal, which is addressed in C7 Disease), this Invasiveness factor is specific to the primary species being farmed. Given that farmed tuna are the product of capture-based aquaculture and that captive tuna originate from the Mediterranean, escapees would pose no additional risk of direct, ecological impacts upon their reintroduction. Consequently, the overall Invasiveness score for farmed bluefin tuna in the Mediterranean is 10 out of 10.

Escape Criterion—Conclusions and Final Score

Although the ongoing potential for bluefin tuna escapes from a high-risk production system are significant, invasive impacts are considered low for captured wild tuna that escape into their original environment. With no adjustment for Recapture and Mortality, the Escape Criterion score is 10 out of 10.

Criterion 7. Disease; pathogen and parasite interactions

Impact, unit of sustainability and principle

- *Impact: amplification of local pathogens and parasites on fish farms and their retransmission to local wild species that share the same water body*
- *Sustainability unit: wild populations susceptible to elevated levels of pathogens and parasites.*
- *Principle: aquaculture operations pose no substantial risk of deleterious effects to wild populations through the amplification and retransmission of pathogens or parasites.*

Pathogen and parasite parameters	Score	
C7 Biosecurity	5.00	
C7 Disease; pathogen and parasite Final Score	**5.00**	**YELLOW**
Critical?	**NO**	

Brief Summary

Although bluefin tuna farms are associated with high pathogen prevalence, disease-related mortality in the Mediterranean is generally low. Despite reports of several bacterial outbreaks at juvenile tuna farms in the Adriatic Sea, few regulatory measures are currently employed for pathogen control in the Mediterranean. There is currently no evidence that pathogens or parasites within bluefin tuna farms are causing significant population declines in wild tuna stocks or other wild species, but the lack of regulatory health measures and the well-documented interaction between wild bluefin tuna and aquaculture operations warrant ongoing concern for potential disease transfer between farmed and wild species. These conditions result in a Criterion 7 - Disease score of 5 out of 10 on a precautionary basis.

Justification of Ranking

The open nature of net pens means that farm fish are constantly exposed to ubiquitous pathogens from the surrounding waterbody, from wild fish, or from other captive individuals. As a result, tuna farms can act as a temporary reservoir for a variety of pathogens and parasites that have the potential to affect other wild species in the region.

In the Mediterranean, diseases in wild tuna are caused by a variety of pathogens including parasites, bacteria, and fungi. This large number of disease vectors is compounded in capture-based aquaculture, in which wild fish (whose health and infection status are unknown) are captured and subsequently concentrated into farms (Mladineo 2006). In the Mediterranean, at least 28 species spanning several phyla, including Arthropoda, Aschelminthes, Ciliophora, Myxozoa, and Platyhelminthes, have been identified in farmed bluefin tuna (Erol 2012).

Parasite prevalence and diversity
According to the literature, parasites represent the largest group of pathogens reported in farmed tuna (Mladineo 2006a). A study in Croatia found that 92.9% of all sampled tuna harbored at least one parasite species (Mladineo et al. 2008). Tuna parasitofauna is primarily dominated by trematode flatworms, and the most abundant species (61.75% prevalence) was *Didymocystis wedli* (Mladineo 2006c) (Mladineo et al. 2008) (Mladineo and Bočina 2009). Other studies report blood fluke infection rates of 29.6% (Ybañez et al. 2011), *H. trichiuri* (flatworm) infection rate of 28.4% (Mladineo 2006b), and microsporidia (fungi) infection rate of 9.9% (Mladineo and Lovey 2011).

Disease outbreaks
Although there has been no history of disease outbreaks in Mediterranean tuna fattening farms to date, juvenile-rearing operations in the Adriatic Sea are particularly susceptible to disease amplification. Several pasteurellosis bacterial outbreaks resulting in mortalities in Croatian tuna farms have been attributed to farming characteristics specific to juvenile rearing, including prolonged rearing cycles, the use of juvenile tuna (which are successively younger at each stocking and consequently more vulnerable to infection), and the integration of individuals from different capture seasons into the same net pen cluster (Raynard et al. 2007) (Mladineo et al. 2008). Furthermore, secondary diseases resulting from inadequate zoosanitary measures were observed at juvenile tuna farms, and poor diet produced additional mortalities during the second summer of rearing (Mladineo 2006c) (Mladineo et al. 2006).

Low mortality rates
Despite the strong prevalence and diversity of pathogens linked to tuna farming, the high number of infectious species generally does not result in intensive proliferation of diseases (Mladineo 2006b) (Mladineo 2006c) (Mladineo et al. 2008) (pers. comm., Malta Aquaculture Research Centre 2015) (pers. comm., Spanish Institute of Oceanography 2015) (pers. comm., Hellenic Center for Marine Research 2015). Typically, a low percentage of mortalities is connected to the spread of pathogens in experimental tank culture of other tuna species *(T. orientalis, T. albacares)*, and the majority of farmed tuna remain in good health (Mladineo et al. 2008). Unlike bacterial infections in Croatian tuna farms, "no mortalities related to parasitic infections have been reported in the captive *T. thynnus*" in the Mediterranean, and it has been demonstrated that parasite levels decrease over the rearing period (Mladineo et al. 2011). The lack of pathogen amplification seen in tuna fattening farms has been attributed to siting in relatively exposed marine areas, short rearing times, substantial fallow periods, low stocking density, and the stocking of immuno-competent, mature tuna (Mladineo 2006c) (Mladineo et al. 2008) (Mylonas et al. 2010). Given the low mortality rates caused by pathogens, studies have found farmed bluefin mortality to be more closely related to disease from the use of exotic baitfish, environmental conditions (e.g., suspended particulate matter), and transport stress (Mylonas et al. 2010).

As for juvenile tuna farms, contrary to the heightened potential for bacterial outbreaks, other studies have also observed a decline in both prevalence and abundance of parasite fauna once the fish were adapted to the net pens (Nowak et al. 2006). A study in Croatia reports the disappearance of monoxenous copepods and monogenean species as well as a significant decrease in heteroxenous digeneans, where the parasitic population exhibited a significant decreasing trend at the end of the rearing cycle (Mladineo et al. 2011) (Arechavala López et al. 2013). The authors of the studies suggest that the absence of intermediate hosts over extended rearing periods could prevent parasites from successfully reproducing, but further concluded that environmental, anthropogenic, and host-intrinsic factors were also responsible for reducing the parasite population. These findings suggest that no general rule can be applied to the bluefin tuna farming industry, and that specific disease management plans are important.

Introduced pathogens

Although no foreign diseases have been introduced into the Mediterranean through bluefin tuna farming, it is worth mentioning that the use of whole baitfish as feed has a high potential to act as a vector for introducing exotic pathogens.

The globalized sourcing of feedfish for bluefin tuna farming potentially enables pathogenic, exogenous microorganisms to enter the Mediterranean and subsequently propagate diseases, and susceptible wild fish populations could suffer mortalities (Raynard et al. 2007). Of particular concern is the spread of viral haemorrhagic septicaemia (harbored in herrings) to other susceptible naive baitfish populations, and digenean trematodes that use baitfish as an intermediate host prior to infecting tuna (Mladineo et al. 2008) (Mladineo and Bočina 2009). In addition, the dissemination of a virus (via tuna feces, seagulls, or uneaten baitfish) into a foreign environment represents a serious threat to species with a naive immune response (Mladineo et al. 2008). A well-known example of this occurred in farms of Australian southern bluefin tuna *(Thunnus maccoyii)* in 1995 and 1998, where a previously unknown pilchard herpes virus was propagated by exotic baitfish feed, resulting in two mass mortality events in which the native Australian pilchard spawning biomass fell by 75% and 70%, respectively, though it has since recovered (Ward et al. 2007) (WWF, 2005).

Disease management

With no significant history of mass mortality and the absence of remarkable gross pathology or external signs of disease (Mladineo 2006c) (Mladineo 2006d) (Mladineo et al. 2006) (Nowak et al. 2006) (Ybañez et al. 2011), health management is not an aspect that is taken into great consideration in either tuna fattening or juvenile farming operations (Mylonas et al. 2010). Furthermore, since major health problems affecting the market viability of farmed bluefin have yet to be encountered, disease control legislation is virtually absent in the Mediterranean and no effective methods for pathogen control are in place to reduce potentially significant infection rates (Ottolenghi 2008).

In addition to the lack of monitoring and regulatory management, there is no regional record of farmed tuna disease interactions with wild counterparts. The lack of robust data for disease impacts on wild tuna is of particular concern in the Mediterranean, where increasing interactions between wild bluefin tuna and farm sites have been reported (Arechavala-Lopez et al. 2015).

Disease Criterion—Conclusions and Final Score

Overall, there is currently no evidence that pathogens or parasites within bluefin tuna farms are causing significant population declines in wild counterparts (pers. comm., Spanish Institute of Oceanography 2015) (pers. comm., Hellenic Center for Marine Research 2015). Given the high number of pathogens found in bluefin fattening farms and the susceptibility of juvenile-rearing tuna farms to bacterial outbreaks, the potential for tuna farms to amplify pathogens above normal background levels and act as a reservoir continues to be an ongoing concern, due to the lack of regulatory measures to monitor and manage the presence of pathogens. But studies have shown parasite prevalence and abundance to decrease over the rearing period. The potential for introducing exotic pathogens from imported baitfish and consideration of the geographic overlap between the tuna farming industry and the natural migration routes and habitat for the East Atlantic bluefin tuna stock also represent areas of concern for potential disease impacts.

Seafood Watch applies a precautionary principle in situations in which there is significant uncertainty. Therefore, until more reliable data are available, the final score for the Criterion 7 - Disease is 5 out of 10 and reflects the ongoing ecological concern associated with the lack of regulatory oversight and management of diseases and the ensuing absence of data on farmed or wild tuna impacts.

Criterion 8. Source of Stock – independence from wild fisheries

Impact, unit of sustainability and principle

- *Impact: the removal of fish from wild populations for on-growing to harvest size in farms*
- *Sustainability unit: wild fish populations*
- *Principle: aquaculture operations use eggs, larvae, or juvenile fish produced from farm-raised broodstocks, use minimal numbers, or source them from demonstrably sustainable fisheries.*

Source of stock parameters	Score	
C8 % of production from hatchery-raised broodstock, natural (passive) settlement, or sourced from sustainable fisheries	0	
C8 Source of stock Final Score	**0.00**	**RED**

Brief Summary

Mediterranean bluefin tuna farms are considered to be 100% reliant on threatened wild tuna populations due to the industry-wide dependence on wild-caught individuals for farm stock. Thus, the Criterion 8 - Source of Stock score is 0 out of 10.

Justification of Ranking

In the Mediterranean, farmed bluefin tuna are produced using a culture method relying entirely on catching wild tuna, transporting them into net pens, and rearing them as farm stock. The inherently extractive nature of bluefin farming is compounded by the use of juveniles (in Croatia) that have not reached sexual maturity and are prevented from spawning and contributing to wild stocks. The ongoing removal of wild fish for farm production is considered a significant loss of ecosystem services.

Although fully farm-raised Pacific bluefin tuna *(Thunnus orientalis)* are being produced in Japan on a regular basis, hatchery production of bluefin in the Mediterranean is still being developed under experimental conditions in Spain and Turkey through the Self-Sustained Aquaculture and Domestication of Bluefin Tuna *Thunnus thynnus* Project (SELFDOTT).[2] Given that only two fully farm-raised bluefin tuna have ever been sold in the Mediterranean (December 2014 by Fortuna Mare SL) (Ipac 2014), hatchery-based bluefin production has yet to be achieved on a consistent commercial scale (GFCM 2005) (Ottolenghi 2008) (Mylonas et al. 2010) (Longo 2011) (pers. comm., Malta Aquaculture Research Centre 2015) (pers. comm., Hellenic Center for Marine Research 2015). As an inherent part of capture-based aquaculture, Mediterranean tuna farming

[2] (Tallaksen 2014) (http://www.transdott.eu/transdott/, accessed 2/11/15) (pers. comm., Malta Aquaculture Research Centre 2015) (pers. comm., Spanish Institute of Oceanography 2015).

practices clearly overlap with the wild fisheries sector, and access to farm stock is heavily influenced by fisheries regulations and management.

Regional fisheries management organizations are responsible for assessing and regulating bluefin tuna fisheries in the Mediterranean Sea:

1. **International Commission for the Conservation of Atlantic Tunas (ICCAT)**
   ICCAT is an inter-governmental organization responsible for the conservation of bluefin tunas in the Mediterranean. ICCAT uses fishery statistics from its Standing Committee on Research and Statistics (SCRS) to develop management advice on regulatory measures such as setting fishery seasons, TAC quotas, and minimum size standards. ICCAT recommendations are binding to EU Member-States. All bluefin tuna farming nations are members of ICCAT.

- **Establishment of the Mediterranean Sea and Eastern Atlantic Ocean Bluefin Tuna Recovery Plan (2008).**
  Conservation and enforcement measures reduced overall bluefin tuna production capacity in the Mediterranean. In addition to TAC reductions, the plan includes the following measures (ISSF 2013):
  1. Manages fishing capacity (including mandated capacity adjustments to make fishing capacity more commensurate with quotas) and farming capacity
  2. Establishes closed fishing seasons for purse seiners (11 months)
  3. Sets minimum sizes of 8 or 30 kg, depending on the fishery
  4. Establishes record of authorized fishing vessels and farming facilities
  5. Requires weekly catch reports to national agencies and monthly catch reports to ICCAT
  6. Establishes an observer program with 100% coverage for purse seiners and for transfers to net pens
  7. Requires a vessel monitoring systems (VMS) on every vessel over 15 m in length, and transmissions of the VMS data to ICCAT
  8. Prohibits trade of bluefin not accompanied by valid catch documents
  9. Establishes procedures for at-sea boarding and inspection
  10. Allows SCRS to access all MCS data from the management plan

After decades of overfishing and a subsequent 63% decline in population size from 1985–2005, the Mediterranean bluefin tuna stock was listed as “Endangered” under the IUCN Red List, as well as a “Species of Concern” by NOAA. These listings prompted the establishment of the Mediterranean Sea and Eastern Atlantic Ocean Bluefin Tuna Recovery Plan in 2008 (Abdul Malak et al. 2011) (NOAA 2013) (ICCAT 2014). The conservation and enforcement measures of the recovery plan resulted in a substantial decrease in catch and a three- to four-fold increase in juvenile abundance from 2009–2012 (ICCAT 2014).

Despite reports indicating stock recovery, a 2009 study observed that the illegal quantity of farmed juvenile tunas found in Japanese markets pointed to a failure to control illegal capture and continued underreporting by tuna farmers (GFCM 2011b). Similarly, trade-based estimations published in 2013 showed that excess catches of 44% were made from 2005–2011, suggesting that overfishing continues to occur with regularity (Gagern et al. 2013). Although the implementation of the recovery plan resulted in clear reductions in catch and fishing mortality rates, the magnitude and the speed of the increase in standing stock biomass remains highly uncertain (ICCAT 2014) (ISSF 2015).

Source of Stock Criterion—Conclusions and Final Score

Because of the industry-wide use of wild-caught tuna as captive stock, the Mediterranean bluefin tuna farming industry is considered to be fully reliant on the wild bluefin tuna populations for the supply of both mature and juvenile fish. The ongoing removal of threatened fish is extractive and considered a significant loss of ecosystem services. These conditions result in a Criterion 8 - Source of Stock score of 0 out of 10.

Criterion 9X: Wildlife and predator mortalities

A measure of the effects of deliberate or accidental mortality on the populations of affected species of predators or other wildlife.

This is an "exceptional" criterion that may not apply in many circumstances. It generates a negative score that is deducted from the overall final score. A score of zero means there is no impact.

Wildlife and predator mortality parameters	Score	
C9X Wildlife and predator mortality Final Score	**-5.00**	**YELLOW**
Critical?	NO	

Brief Summary
Dolphins, seals, and sharks are the primary wildlife species interacting with bluefin tuna farms and associated purse-seiners, but interactions are rare. For dolphins and seals, Mediterranean fish farms (seabream and sea bass) employ non-lethal methods to deter predators, per EU regulations, though there is no indication they are used at tuna farms. Few reporting obligations exist for bluefin tuna farming, resulting in exceptionally little robust data on their impact to dolphin and seal populations; however, mortalities associated with tuna farming are unlikely to cause population-level impacts. The lack of statistical data available for both farm-related wildlife mortalities and purse seine bycatch, combined with the endangered status of several involved species and the potential for underreporting, result in a precautionary approach to scoring this criterion. The final score for Criterion 9X - Wildlife Mortalities is –5 out of –10.

Justification of Ranking
Throughout the Mediterranean, marine net pens are the dominant farming technique for finfish aquaculture. Interactions between marine wildlife and net pens have been observed frequently, but there is little recently published peer-reviewed literature that specifically addresses this issue. In comparable Australian bluefin tuna operations, anecdotal information indicates that seals, sharks, and dolphins have all been entangled or enclosed and subsequently found dead in tuna net pens (Kemper and Gibbs 2001) (Tanner 2007) (National Seal Strategy Group and Stewardson 2007) (Goldsworthy et al. 2009).

Although little data exist specifically regarding the occurrence and behavior of dolphins around Mediterranean bluefin tuna farms (Sanchez Jerez et al. 2007) (Grigorakis and Rigos 2011), more information is available regarding dolphin interactions with purse seiners fishing for farm stock. Data indicate that few dolphins are accidentally being caught and the majority are released unharmed (Tudela 2004) (Sacchi 2012). Purse seining in the Mediterranean does not, as a general rule, involve the practice of setting nets around cetaceans, resulting in small bycatch rates of nontarget species (Tudela 2004) (ISSF 2013). In contrast, dolphin bycatch is more frequently associated with purse seine operations targeting baitfish, particularly sardine and anchovy, because these small pelagic species represent natural prey items (Tudela 2004) (Ancha 2008) (Sacchi 2012).

Seals may be particularly vulnerable to entanglement in fishing nets because of their innate biological characteristics. Intrinsically, seals will actively seek out fishing nets and fish farm installations to raid for food, and accidental entanglement most commonly affects juvenile seals; however, evidence points to seals interacting with seabream and sea bass farms rather than tuna farms, likely because tuna is not a natural prey item (Karamanlidis et al. 2008). Although entanglement continues to be a threat to individual seals, the number of seals caught accidentally in fishing gear and anti-predator nets represents a minor proportion of the total population (Karamanlidis et al. 2008). Overall, the primary factor contributing to population decline and seal mortality is intentional killing by fishers, whereas entanglement in nets alone is insufficient to cause population-level impacts (Karamanlidis et al. 2016) (RAC/SPA 2005).

Wildlife management

Regulatory management for these wildlife interactions falls under the purview of individual Member-States, which are required to implement EU policies for protected marine species. These policies are modeled by habitat conservation legislation (Habitats Directive, Strategy for the Marine Environment Directive, Regulation on the Conservation and Sustainable Exploitation of these Resources in the Mediterranean) as well as international species conservation agreements established by the IUCN and CITES. Outside the EU, tuna farming countries such as Turkey and Tunisia regulate bycatch using their own regulations.

Per EU regulations, aquaculture operations typically employ non-lethal methods to deter predators. Though there is no indication that these are used at tuna farms, other aquaculture operations widely use control methods including underwater nets and acoustic devices, such as acoustic harassment devices (AHDs), acoustic deterrent devices (ADDs, including “pingers”), or acoustic mechanical systems (Bearzi et al. 2008) (López 2012). The effectiveness of these deterrents is questionable because there is a potential for a “dinner bell” effect, resulting in increased interactions (Bearzi et al. 2008).

Other predator deterrent methods include harassment by boat or with noise (such as underwater seal firecrackers), aversive conditioning, models or sounds of predators (e.g., killer whales), and relocation, in the case of seals. The harassment techniques overall are often only effective in the short term and become less efficacious over time as animals become habituated (Price et al. 2013).

In addition to the species mentioned, a variety of different whales (minke, sei, fin, short-finned pilot, killer, sperm, false killer), dolphins (common, striped, rough-toothed, bottlenose), sea turtles (loggerhead, green turtle, leatherback, hawksbill), and sharks (white [pers. comm., Spanish Institute of Oceanography 2015], blue, shortfin mako) have been caught incidentally by entanglement in anti-predator nets, from purse seining on free schools of bluefin tuna, or from entrapment in tuna net pens (Galaz and Maddalena 2004) (Ancha 2008) (Karamanlidis et al. 2008).

At the EU level, bycatch reporting is a mandatory requirement for wild-capture tuna purse seine fisheries, but few reporting obligations exist for bluefin tuna farms, resulting in exceptionally little robust data on their interactions with bycatch species. Although mortalities appear to be limited (pers. comm., Spanish Institute of Oceanography 2015) (pers. comm., Hellenic Center for Marine Research 2015), a number of bycatch species are listed as being "Vulnerable" (bottlenose dolphin), "Endangered" (white shark), and "Critically Endangered" (monk seal) by the IUCN. Given the potential for unreported encounters (Galaz and Maddalena 2004) and the overall lack of reporting requirements for bluefin tuna farms, ongoing concern remains over the impact of bluefin tuna farming on these species.

Wildlife and Predator Mortalities Criterion—Conclusions and Final Score

Overall, wildlife interactions are considered rare in bluefin tuna farming, because the bycatch of dolphins primarily revolves around baitfish purse seine fisheries, and predator nets at tuna farm sites produce few, if any, seal and/or shark mortalities. The lack of statistical data available for farm-related encounters and mortalities combined with the endangered status of some bycatch species result in a precautionary approach to this exceptional criterion.

Note that this is an "exceptional" criterion and the scoring range is from 0 (no concern) to –10 (very high concern). The final score for Criterion 9X - Wildlife and Predator Mortalities is –5 out of –10.

Criterion 10X: Escape of unintentionally introduced species

A measure of the escape risk (introduction to the wild) of alien species other than the principle farmed species unintentionally transported during live animal shipments.

This is an "exceptional" criterion that may not apply in many circumstances. It generates a negative score that is deducted from the overall final score.

Escape of unintentionally introduced species parameters	Score	
F10Xa International or trans-waterbody live animal shipments (%)	10.00	
F10Xb Biosecurity of source/destination	2.00	
C6 Escape of unintentionally introduced species Final Score	**0.00**	**GREEN**

Brief Summary

In Mediterranean bluefin tuna farming, wild stocks are captured and transported to net pens within the same waterbody, so the unintentional introduction of non-native species does not occur. The final score for Criterion 10X - Escape of unintentionally introduced species is 0 out of –10.

Justification of Ranking

In the Mediterranean, bluefin tuna farming is recognized as a capture-based aquaculture practice that relies on wild stocks that are native to the region. The unintentional introduction of non-native species does not occur.

Factor 10Xa International or trans-waterbody live animal shipments

Atlantic bluefin tuna grown in Mediterranean net pens are wild stocks native to the region. None of the industry relies on international or trans-waterbody live animal shipments, resulting in a Factor 10Xa score of 10 out of 10.

With no international or trans-waterbody animal movements, Factor 10Xb is not applicable.

Escape of Introduced Species Criterion—Conclusions and Final Score

In Mediterranean bluefin tuna farming, wild stocks are captured and transported to net pens within the same waterbody, so the unintentional introduction of non-native species does not occur. The final score for Criterion 10X - Escape of unintentionally introduced species is 0 out of –10.

Overall Recommendation

The overall recommendation is as follows:

The overall final score is the average of the individual criterion scores (after the two exceptional scores have been deducted from the total). The overall ranking is decided according to the final score, the number of red criteria, and the number of critical scores as follows:

– **Best Choice** = Final score ≥6.6 AND no individual criteria are Red (i.e. <3.3)
– **Good Alternative** = Final score ≥3.3 AND <6.6, OR Final score ≥ 6.6 and there is one individual Red criterion.
– **Red** = Final score <3.3, OR there is more than one individual Red criterion, OR there is one or more Critical score.

Criterion	Score (0-10)	Rank	Critical?
C1 Data	6.11	YELLOW	
C2 Effluent	5.00	YELLOW	NO
C3 Habitat	4.27	YELLOW	NO
C4 Chemicals	10.00	GREEN	NO
C5 Feed	0.00	CRITICAL	YES
C6 Escapes	10.00	GREEN	NO
C7 Disease	5.00	YELLOW	NO
C8 Source	0.00	RED	
C9X Wildlife mortalities	-5.00	YELLOW	NO
C10X Introduced species escape	0.00	GREEN	
Total	**35.38**		
Final score	**4.42**		

OVERALL RANKING

Final Score	4.42
Initial rank	YELLOW
Red criteria	2
Interim rank	RED
Critical Criteria?	YES

FINAL RANK
RED

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Scientific review does not constitute an endorsement of the Seafood Watch® program, or its seafood recommendations, on the part of the reviewing scientists. Seafood Watch® is solely responsible for the conclusions reached in this report.

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About Seafood Watch®

Monterey Bay Aquarium's Seafood Watch® program evaluates the ecological sustainability of wild-caught and farmed seafood commonly found in the United States marketplace. Seafood Watch® defines sustainable seafood as originating from sources, whether wild-caught or farmed, which can maintain or increase production in the long-term without jeopardizing the structure or function of affected ecosystems. Seafood Watch® makes its science-based recommendations available to the public in the form of regional pocket guides that can be downloaded from www.seafoodwatch.org. The program's goals are to raise awareness of important ocean conservation issues and empower seafood consumers and businesses to make choices for healthy oceans.

Each sustainability recommendation on the regional pocket guides is supported by a Seafood Report. Each report synthesizes and analyzes the most current ecological, fisheries and ecosystem science on a species, then evaluates this information against the program's conservation ethic to arrive at a recommendation of "Best Choices", "Good Alternatives" or "Avoid". The detailed evaluation methodology is available upon request. In producing the Seafood Reports, Seafood Watch® seeks out research published in academic, peer-reviewed journals whenever possible. Other sources of information include government technical publications, fishery management plans and supporting documents, and other scientific reviews of ecological sustainability. Seafood Watch® Research Analysts also communicate regularly with ecologists, fisheries and aquaculture scientists, and members of industry and conservation organizations when evaluating fisheries and aquaculture practices. Capture fisheries and aquaculture practices are highly dynamic; as the scientific information on each species changes, Seafood Watch®'s sustainability recommendations and the underlying Seafood Reports will be updated to reflect these changes.

Parties interested in capture fisheries, aquaculture practices and the sustainability of ocean ecosystems are welcome to use Seafood Reports in any way they find useful. For more information about Seafood Watch® and Seafood Reports, please contact the Seafood Watch® program at Monterey Bay Aquarium by calling 1-877-229-9990.

Disclaimer
Seafood Watch® strives to have all Seafood Reports reviewed for accuracy and completeness by external scientists with expertise in ecology, fisheries science and aquaculture. Scientific review, however, does not constitute an endorsement of the Seafood Watch® program or its recommendations on the part of the reviewing scientists. Seafood Watch® is solely responsible for the conclusions reached in this report.

Guiding Principles

Seafood Watch™ defines sustainable seafood as originating from sources, whether fished[3] or farmed, that can maintain or increase production in the long-term without jeopardizing the structure or function of affected ecosystems.

The following **guiding principles** illustrate the qualities that aquaculture must possess to be considered sustainable by the Seafood Watch program:

Seafood Watch will:

- Support data transparency and therefore aquaculture producers or industries that make information and data on production practices and their impacts available to relevant stakeholders.
- Promote aquaculture production that minimizes or avoids the discharge of wastes at the farm level in combination with an effective management or regulatory system to control the location, scale and cumulative impacts of the industry's waste discharges beyond the immediate vicinity of the farm.
- Promote aquaculture production at locations, scales and intensities that cumulatively maintain the functionality of ecologically valuable habitats without unreasonably penalizing historic habitat damage.
- Promote aquaculture production that by design, management or regulation avoids the use and discharge of chemicals toxic to aquatic life, and/or effectively controls the frequency, risk of environmental impact and risk to human health of their use
- Within the typically limited data availability, use understandable quantitative and relative indicators to recognize the global impacts of feed production and the efficiency of conversion of feed ingredients to farmed seafood.
- Promote aquaculture operations that pose no substantial risk of deleterious effects to wild fish or shellfish populations through competition, habitat damage, genetic introgression, hybridization, spawning disruption, changes in trophic structure or other impacts associated with the escape of farmed fish or other unintentionally introduced species.
- Promote aquaculture operations that pose no substantial risk of deleterious effects to wild populations through the amplification and retransmission of pathogens or parasites.
- Promote the use of eggs, larvae, or juvenile fish produced in hatcheries using domesticated broodstocks thereby avoiding the need for wild capture

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331 "Fish" is used throughout this document to refer to finfish, shellfish and other

invertebrates.

- Recognize that energy use varies greatly among different production systems and can be a major impact category for some aquaculture operations, and also recognize that improving practices for some criteria may lead to more energy intensive production systems (e.g. promoting more energy-intensive closed recirculation systems)

Once a score and rank has been assigned to each criterion, an overall seafood recommendation is developed on additional evaluation guidelines. Criteria ranks and the overall recommendation are color-coded to correspond to the categories on the Seafood Watch pocket guide:

Best Choice/Green: Buy first, they're well managed and caught or farmed in ways that cause little harm to habitats or other wildlife.

Good Alternative/Yellow: Buy, but be aware there are concerns with how they're caught or farmed.

Avoid/Red: Don't buy, they're overfished or caught or farmed in ways that harm other marine life or the environment.

Appendix 1 – Data points and all scoring calculations

Criterion 1: Data quality and availability

Data Category	Relevance (Y/N)	Data Quality	Score (0-10)
Industry or production statistics	*Yes*	2.5	2.5
Effluent	Yes	7.5	7.5
Locations/habitats	Yes	7.5	7.5
Chemical use	Yes	7.5	7.5
Feed	Yes	7.5	7.5
Escapes, animal movements	Yes	7.5	7.5
Disease	Yes	2.5	2.5
Source of stock	Yes	10	10
Predators and wildlife	Yes	2.5	2.5
Other – (e.g. GHG emissions)	No	Not relevant	n/a
Total			**55**

C1 Data Final Score	6.1	YELLOW

Criterion 2: Effluents

Factor 2.1a - Biological waste production score

Protein content of feed (%)	19.2
eFCR	25
Fertilizer N input (kg N/ton fish)	0
Protein content of harvested fish (%)	21.55
N content factor (fixed)	*0.16*
N input per ton of fish produced (kg)	768
N in each ton of fish harvested (kg)	34.48
Waste N produced per ton of fish (kg)	**733.52**

Factor 2.1b - Production System discharge score

Basic production system score	0.8
Adjustment 1 (if applicable)	0
Adjustment 2 (if applicable)	0
Adjustment 3 (if applicable)	0
Discharge (Factor 2.1b) score	**0.8**

80% of the waste produced by the fish is discharged from the farm

2.2 – Management of farm-level and cumulative impacts and appropriateness to the scale of the industry

Factor 2.2a - Regulatory or management effectiveness

Question	Scoring	Score
1 - Are effluent regulations or control measures present that are designed for, or are applicable to aquaculture?	Moderately	0.5
2 - Are the control measures applied according to site-specific conditions and/or do they lead to site-specific effluent, biomass or other discharge limits?	Partly	0.25
3 - Do the control measures address or relate to the cumulative impacts of multiple farms?	Moderately	0.5
4 - Are the limits considered scientifically robust and set according to the ecological status of the receiving water body?	Partly	0.25
5 - Do the control measures cover or prescribe including peak biomass, harvest, sludge disposal, cleaning etc?	Moderately	0.5

Factor 2.2b - Enforcement level of effluent regulations or management

Question	Scoring	Score
1 - Are the enforcement organizations and/or resources identifiable and contactable, and appropriate to the scale of the industry?	Mostly	0.75
2 - Does monitoring data or other available information demonstrate active enforcement of the control measures?	Partly	0.25
3 - Does enforcement cover the entire production cycle (i.e. are peak discharges such as peak biomass, harvest, sludge disposal, cleaning included)?	Yes	1
4 - Does enforcement demonstrably result in compliance with set limits?	Partly	0.25
5 - Is there evidence of robust penalties for infringements?	Moderately	0.5

F2.2 Score (2.2a*2.2b/2.5)	2.2

C2 Effluent Final Score	5.00	YELLOW
	Critical?	NO

Criterion 3: Habitat

3.1. Habitat conversion and function

F3.1 Score	5

3.2 Habitat and farm siting management effectiveness (appropriate to the scale of the industry)

Question	Scoring	Score
1 - Is the farm location, siting and/or licensing process based on ecological principles, including an EIAs requirement for new sites?	Mostly	0.75
2 - Is the industry's total size and concentration based on its cumulative impacts and the maintenance of ecosystem function?	Mostly	0.75
3 – Is the industry's ongoing and future expansion appropriate locations, and thereby preventing the future loss of ecosystem services?	Mostly	0.75
4 - Are high-value habitats being avoided for aquaculture siting? (i.e. avoidance of areas critical to vulnerable wild populations; effective zoning, or compliance with international agreements such as the Ramsar treaty)	Moderately	0.5
5 - Do control measures include requirements for the restoration of important or critical habitats or ecosystem services?	Mostly	0.75
		3.5

Question	Scoring	Score
1 - Are enforcement organizations or individuals identifiable and contactable, and are they appropriate to the scale of the industry?	Moderately	0.5
2 - Does the farm siting or permitting process function according to the zoning or other ecosystem-based management plans articulated in the control measures?	Moderately	0.5
3 - Does the farm siting or permitting process take account of other farms and their cumulative impacts?	Moderately	0.5
4 - Is the enforcement process transparent - e.g. public availability of farm locations and sizes, EIA reports, zoning plans, etc?	Partly	0.25
5 - Is there evidence that the restrictions or limits defined in the control measures are being achieved?	Partly	0.25

F3.2 Score (2.2a*2.2b/2.5)	2.80

C3 Habitat Final Score	4.27	YELLOW
	Critical?	NO

Criterion 4: Evidence or Risk of Chemical Use

Chemical Use parameters	Score	
C4 Chemical Use Score	**10.00**	
C4 Chemical Use Final Score	**10.00**	GREEN
Critical?	NO	

Criterion 5: Feed

5.1. Wild Fish Use

Factor 5.1a - Fish In: Fish Out (FIFO)

Fishmeal inclusion level (%)	22.5
Fishmeal from by-products (%)	0
% FM	22.5
Fish oil inclusion level (%)	5
Fish oil from by-products (%)	0
% FO	5
Fishmeal yield (%)	22.5
Fish oil yield (%)	5
eFCR	20
FIFO fishmeal	20.00
FIFO fish oil	20.00
Greater of the 2 FIFO scores	20.00
FIFO Score	**0.00**

Factor 5.1b - Sustainability of the Source of Wild Fish (SSWF)

SSWF	-6
SSWF Factor	-12

F5.1 Wild Fish Use Score	**0.00**

5.2. Net protein Gain or Loss

Protein INPUTS	
Protein content of feed	19.2
eFCR	20
Feed protein from NON-EDIBLE sources (%)	0

Feed protein from EDIBLE CROP soruces (%)	0
Protein OUTPUTS	
Protein content of whole harvested fish (%)	21.55
Edible yield of harvested fish (%)	69.13
Non-edible by-products from harvested fish used for other food production	50
Protein IN	384.00
Protein OUT	18.2237575
Net protein gain or loss (%)	-95.25422982
Critical?	YES

F5.2 Net protein Score	**0.00**

5.3. Feed Footprint

5.3a Ocean area of primary productivity appropriated by feed ingredients per ton of farmed seafood

Inclusion level of aquatic feed ingredients (%)	27.5
eFCR	20
Average Primary Productivity (C) required for aquatic feed ingredients (ton C/ton fish)	*69.7*
Average ocean productivity for continental shelf areas (ton C/ha)	*2.68*
Ocean area appropriated (ha/ton fish)	143.04

5.3b Land area appropriated by feed ingredients per ton of production

Inclusion level of crop feed ingredients (%)	0
Inclusion level of land animal products (%)	0
Conversion ratio of crop ingredients to land animal products	*2.88*
eFCR	20
Average yield of major feed ingredient crops (t/ha)	*2.64*
Land area appropriated (ha per ton of fish)	0.00

Value (Ocean + Land Area)	**143.04**

F5.3 Feed Footprint Score	**0.00**

C5 Feed Final Score	**0.00**	**CRITICAL**
	Critical?	**YES**

Escape Risk	**2**

Recapture & Mortality Score (RMS)	
Estimated % recapture rate or direct mortality at the escape site	0
Recapture & Mortality Score	0
Factor 6.1a Escape Risk Score	**2**

6.1b. Invasiveness

Part A – Native species

Score	5

Part B – Non-Native species

Score	**0**

Question	
Do escapees compete with wild native populations for food or habitat?	
Do escapees act as additional predation pressure on wild native populations?	
Do escapees compete with wild native populations for breeding partners or disturb breeding behavior of the same or other species?	
Do escapees modify habitats to the detriment of other species (e.g. by feeding, foraging, settlement or other)?	
Do escapees have some other impact on other native species or habitats?	

F 6.1b Score	**10**

Final C6 Score	**10.00**	**GREEN**
	Critical?	**NO**

Criterion 7: Diseases

Pathogen and parasite parameters	Score	
C7 Biosecurity	5.00	
C7 Disease; pathogen and parasite Final Score	**5.00**	**YELLOW**
Critical?	NO	

Criterion 8: Source of Stock

Source of stock parameters	Score	
C8 % of production from hatchery-raised broodstock, natural (passive) settlement, or sourced from sustainable fisheries	0	
C8 Source of stock Final Score	**0**	**RED**

Wildlife and predator mortality parameters	Score	
C9X Wildlife and Predator Final Score	**-5.00**	**YELLOW**
Critical?	NO	

Criterion 10X: Escape of unintentionally introduced species

Escape of unintentionally introduced species parameters	Score	
F10Xa International or trans-waterbody live animal shipments (%)	10.00	
F10Xb Biosecurity of source/destination	2.00	
C10X Escape of unintentionally introduced species Final Score	**0.00**	**GREEN**

Appendix 2 – Interim Update

An Interim Update of this assessment was conducted in February 2021. Interim Updates focus on an assessment's limiting (i.e. Critical or Red) criteria (inclusive of a review of the availability and quality of data relevant to those criteria), so this review evaluates Criterion 5 Feed and Criterion 8x Source of Stock. No information was found or received that would suggest the final rating is no longer accurate. No edits were made to the text of the report (except an update note in the Executive Summary). The following text summarizes the findings of the review.

Criterion 1 – Data
The availability and quality of data for Atlantic bluefin tuna farmed in the Mediterranean in net pens is moderate overall. Data for Criterion 5 – Feed were captured from peer reviewed literature, although the most recent readily available publications documenting production practices and performance are from 2016. Data for Criterion 8x – Source of stock were readily available, however, there is a lack of a fishery assessment evaluating the potential ecological impacts of purse seine fisheries corralling wild juveniles for tuna ranching operations. As a result, the availability of information for each Criterion (e.g., Feed and Source of Stock) in this interim update is moderate.

Criterion 5 – Feed
In the 2016 SFW assessment of Mediterranean net pen Atlantic bluefin tuna (ABFT) aquaculture production, all farms applied whole fish as the exclusive feed source and there is no readily available evidence in primary literature or other sources that demonstrate feed practices have diverged from the analysis of the 2016 assessment. The whole fish diet consists of a diversity of speices: "Sardinella, Sardina, Clupea, Scomber, Trachurus, sparid *Boops boops* and some cephalopods" (Vita et al., 2004; Aguado et al., 2004 from Die, D. 2016) that may be frosted or frozen (de la Ga´ndara et al., 2016). An estimated total annual demand to "supply Atlantic bluefin tuna farms is between 168 and 362 thousand tons" (Metian et al., 2014; from Mrčelić et al 2020). Farmers monitor and observe tuna behavior to help better manage feed, and during summer months when water temperatures have increased along with the metabolism – termed the fattening season – they are overfed. Tuna are typically fed 1-3 times daily, but can be fed up to 6 times per day (de la Ga´ndara et al., 2016). "The highest food consumption occurs at temperatures of 23- 25°C, which can result in an increase of biomass of more than 10%" (Katavić et al., 2003; from Mrčelić et al 2020).

There is no primary literature readily available that suggests that the eFCR for bluefin tuna caught by purse seines and fattened in net pens in the Mediterranean has significantly changed since the 2016 report. Recent publications are still using eFCR values consistent with the previous findings (Fernando de la Ga´ndara et al 2016; Mrčelić et al 2020) of the 2016 SFW assessment of ABFT, which estimated an eFCR of 20:1. This reflects eFCR values from juveniles ranging from 10-15:1 (Aguado-Giménez and García-García, 2005; Ottolenghi, 2008; Mylonas et al. 2010), and adults ranging from 10-30:1 (Aguado-Giménez and García-García 2005; Vezzuli et al. 2008; Ottolenghi 2008; Mylonas et al. 2010; Longo 2011; Moraitis et al. 2013). Therefore, the eFCR of 20:1 is still considered to accurately reflect current production.

In the Seafood Watch Standard for Aquaculture, Criterion 5 – Feed, evaluates the amount and sustainability of wild fish caught for feeding to farmed fish, the global impacts of harvesting or cultivating feed ingredients, and the net nutritional gains or losses from the farming operation. If the eFCR is ≥4, then the Feed criterion will be ‘Critical’. There is no evidence that the tuna industry has significantly substituted whole fish with pelleted feed. Since feeding practices haven’t changed, the eFCR is not likely to have significantly changed in response, and the eFCR reported in the 2016 assessment is highly likely to be still applicable. Therefore, the Feed Criterion score is still ‘Critical’ for tuna net pen operations in the Mediterranean.

Criterion 8x – Source of Stock

Closing the life cycle of Atlantic bluefin tuna by developing a successful broodstock, hatchery, grow out to harvest tuna production cycle is a significant research and investment priority for the industry. As discussed in the recent *The Fish Site* article by Minkoff and Beijnen (2020), there are a number of hatchery facilities in Europe that are in different stages of operation. Spain’s Instituto Español de Oceanografía (IEO) full cycle tuna research facility has a domesticated broodstock that is expected to begin spawning in the year 2020 (an update on the spawning success was unavailable during the writing of this assessment). There are other hatchery facilities that rear larvae collected from spawning events at ABFT net pen ranches (Zohar et al., 2016; de la Ga´ndara et al., 2016), but these are also 100% reliant on wild ABFT. The percentage of harvested farmed ABFT from the Mediterranean that are sourced from hatcheries (closed or open cycle) appears very minimal, but exact estimates were not readily available. Therefore, it is assumed 100% of farmed ABFT is sourced from wild ABFT.

Since there is a reliance on wild ABFT stock for the sourcing of ranching aquaculture production from the Mediterranean, the abundance of these wild populations and impacts of the fishery activities to ocean ecosystems are important to evaluate the sustainability of the industry. Wild ABFT are caught by purse seine fishing fleets in the “Mediterranean Sea from May to July” (de la Ga´ndara et al., 2016). Tuna are then transported in towing cages to net pens. The abundance of the Mediterranean and Eastern Mediterranean stock was considered Endangered according to the IUCN in 2009. Due to reduced fishing pressure and mortality, the stock status has recently improved. However, according to the 2020 Seafood Watch assessment of Eastern Atlantic and Mediterranean ABFT stock caught using drifting long lines fishing gear, there is still a ‘high concern’ for ABFT stock abundance, but the current fishing mortality is a ‘low concern’. The overall Seafood Watch rating for drifting long line fisheries targeting Eastern Atlantic and Mediterranean ABFT stock are red, Avoid, but the purse seine fisheries capturing Eastern Atlantic and Mediterranean ABFT stock are not currently assessed by Seafood Watch. Therefore, in the absence of a fishery assessment, which considers additional metrics (in addition to abundance and mortality; see Seafood Watch Standard for Fisheries) a precautionary approach of relying on the population abundance is used to inform Criterion 8x – Source of stock.

In the Seafood Watch Standard for Aquaculture, Criterion 8x evaluates the source of farm stock and its independence from wild stocks. Seafood Watch considers capturing wild fish, even from a sustainable fishery, and raising them on a farm to be a net loss of resources and ecosystem services. A score of ‘Critical’ is assigned if there is sourcing of wild juveniles and/or broodstock that are considered endangered, protected, vulnerable, threatened, or critically endangered by the IUCN Red List or by a national or other official list with equivalent categories. Since wild ABFT stock abundance is of a high concern and 100% of ABFT raised in ranching operations are sourced from wild ABFT stock, the score for Criterion 8x is Critical for Mediterranean ABFT net pen production.

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